1988
Get Away Special
Experimenter's
Symposium

1988
Get Away Special Experimenter's Symposium

Edited by
Lawrence R. Thomas
Goddard Space Flight Center
Greenbelt, Maryland

Frances L. Mosier
RMS Technologies, Inc.
Landover, Maryland

∩∧S∧
National Aeronautics
and Space Administration

Scientific and Technical
Information Division

1988

CONTENTS

PRECEDING PAGE BLANK NOT FILMED

CONTENTS (Continued)

THE FIRST CHINESE STUDENT SPACE SHUTTLE GETAWAY SPECIAL PROGRAM

Mark C. Lee,* Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109
Jin Xun-Shu and Ke Shou-Quan, Chinese Academy of Space Technology, Beijing Institute of Environment Test Engineering, Beijing, China
Fu Bing-Chen, Chinese Society of Astronautics, Beijing, China

Abstract

The first Chinese Getaway Special program, including program organization, student proposal evaluation procedure, contents of some of the finalists' experiments, will be presented. Specifically, the two experiments selected for the eventual flight on the Space Shuttle will be described in detail.

1.0 The Chinese GAS Program

The first Chinese student US space shuttle getaway special (GAS) program was jointly organized and sponsored by American Association for Promotion of Science in China (AAPSC), a Los Angeles-based nonprofit organization, and Chinese Society of Astronautics (CSA), based in Beijing, China. The agreement was signed on December 27, 1985 in Beijing, China. The call for proposals from vast population of Chinese secondary school students, estimated at 150 millions strong, was announced in January 1986. Over seven thousand proposals were submitted before the end of summer, in spite of the demoralization caused by the Challenger disaster. Those proposals were evaluated by a two-tier process. First, the proposals were presented and defended orally by student proposers at nine regional locales approximately evenly distributed throughout China. Those regional symposia, actively participated by six experts from the States and many of their Chinese counterparts, produced a total of 264 regional proposals for further consideration in the national symposium to be held during the Christmas season of 1986, in Beijing, China. The national proposal

* Current on assignment to Microgravity Science and Applications Division, NASA Headquarters, Washington, D.C. 20546

evaluation committee consisted of seven American and twenty-five Chinese experts whose specialties covered a broad range of space science and technology disciplines.

The criteria that they had applied uniformly throughout the entire selection process were based on the proposal creativity, scientific merits, experiment feasibility and organization. The committee certainly went through quite a difficult time in deciding what to accept or decline. Nevertheless, twenty proposals were selected as the national finalists. Those proposals, as well as those not chosen, were generally of surprisingly good quality considering the severe handicap that the Chinese students must cope in search for information needed for the research topic. The titles for those twenty proposals are:

1. Control of debris in the cabin of space shuttle, by Wang Nian-qing
2. Solidification of two immiscible liquids in space, by Tian Chun-Liang
3. Effect of cosmic ray on pharmaceutical products, by Shi Gang
4. Effect of μg on plant cell reproduction, by Zhao Quan-Zhong
5. Effect of μg on onion cell reproduction, by Tian Yu-Zhi
6. Application of Velcro in space, by Wang Hai-jiang
7. Observation of surface tension under μg, by Zhou Yan
8. Effect of μg on germinatn of Chinese herb seeds, by Huang Zheng-Chong
9. Ice formation at different temperatures under μg, by Liu Zhong
10. Healing worm injury under μg, by He Kai
11. Mixing paraffin, water and ice under μg, by Zhu Lei
12. Speeding up chemical reactions under μg, by Huang Wen-Ge
13. Gas and liquid phase separation under μg, by Liu Shu-Xiang
14. Coating and capillary absorption under μg, by He Bin
15. Making Tofu in space, by Zhan Han-Jing
16. Behavior of NaCl solution droplet in E field under μg, by Song Yang
17. Property of liquid crystal under μg, by Zhang Jin-Song
18. Effect of μg on Chinese painting, by Zhang Qin-Mei
19. Effect of μg on germintn./reprod. of Chinese mushroom, by Shen Zhong
20. Feathered Ying-luo plant growth in space, by Jiang Yong-Bo

The first two(#1 and 2) experiments were further designated, after hours of heated debate among committee members and final settlement with a secret balloting, as the first Chinese student microgravity payload for a future US space shuttle flight. The third proposal was selected as the back-up. The hardwares for carrying out the GAS experiments are in the process of being developed and fabricated by Beijing Institute of

I

Environment Test Engineering(BIETE). The qualification for flight in space shuttle is scheduled to complete in the second quarter of 1988.

To commemorate this event, a logo has been designed (Fig. 1). The lone star in the sky of the Great Wall signifies that it is the first such event in China.

Figure 1. The logo to commemorate the Chinese student space shuttle getaway special program. The lone star in the sky of the Great Wall signifies the first such event in China.

2.0 Student Experiments

Experiment 1: "**The control of debris in the cabin of space shuttle,**" by Wang Nian-Qing

The purpose of the experiment is to study the motion of debris (small particulates) in the cabin of shuttle under the microgravity condition. A certain amount of simulated particulated debris are stored in a container, a side wall of which is covered with a sheet of adhesive paper. A movie camera will be mounted in the container to photograph the motion of debris upon their release in the microgravity environment and to record the moment when they make contact with the side wall and are captured. From a practical point of view, this simple technique could be applied to

3

remove floating particulates from the living environment in space. In addition, the particulates rely on the residual gravity to initiate the movement. The mathmatical modelling of the experiment could be related to the pseudo-random walk problem. It is highly probable that the residual magnitude of the gravitational field on the shuttle can be backed out from the statistical measurement of those particulate movements.

Experiment 2: **"The solidification of two immiscible liquids in space"** by Tian Chun-Liang

Two immiscible low melt-point materials (Wood's metal and paraffin) will be premixed in various ratios and manners in the solid form on earth and remelted in space, then left to cool and resolidify. It is predicted that paraffin and Wood's metal be phase separated and assume amorphous and crystalline structures, respectively. Depending on the magnitude of the residual gravitational field in the shuttle, the two phases may be uniformly mixed or droplets of the same species may coalesce to form large conglomerates due to the nature tendency for a physical system to minimize its total internal free energy. The samples are to be post-flight analyzed.

3.0 Experimental Apparatus

3.1 Size and weight of the payload: 2.5 cubic feet, 60 pounds.

3.2 Experiment description:

Experiment 1: In this experiment 25 small lumps of different materials to be used as "space debris" or "particulates" will be stored in a container. A side wall will be coated with adhesive cloth. An 8 millimeter movie camera will be installed to view the adhesive wall, to photograph the motion of those small bits of debris after being released under microgravity conditions, and to record the moment when they make contact with the wall. It is desired that every collision of a particulate with the adhesive wall will result in a capture by the wall. However, this is not a prerequisite for the success of the experiment. The camera will be controlled and pictures will be taken at a preprogrammed time sequence. The container will be maintained intact for further post-flight analyses.

Experiment 2: 8 small cylindrical containers, each 2 cm in diameter and 6 cm in height, will be loaded with paraffin and Wood's metal mixtures in

I

different ratios and manners. The two heaters are of foil-type, each powers 4 cylinders. The heating and cooling sequence are preprogrammed. Those containers will be left intact after the space experimentation so that they can be post-flight analyzed.

3.3 Supporting Structure

To provide added thermal insulation, the entire experimental apparatus will be housed in foam/fiberglass composite shells within the GAS canister. These hexagonal type structures are the same as the "spacepak" used in the similar payload in the past GAS flights. Experiment #1 will be stacked on top of the Experiment 2 in a two-spacepak configuration.

The spacepaks will be held by three sets of aluminum ribs on the exterior. At one end of the rib assembly is an aluminum ring with bolt holes for securement to the experiment mounting plate. At the opposite end of the rib assembly, there are three separate bumpers to provide lateral support of the payload within the container.

Figures 2 and 3 show the top view of those two experiments. Each
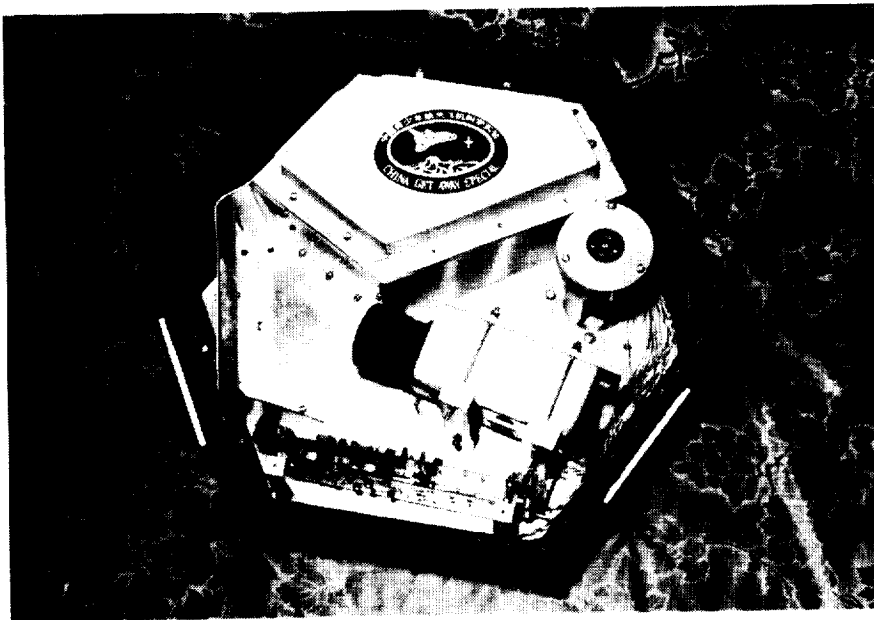
Figure 2. Top view for experiment #1. Initially, the debris are confined inside the right half of the chamber (marked by the logo) by a partition to slide open in the orbit.

5

experiment has its own controller and power supply. All batteries are installed in the second spacepak.

3.4 Controllers and Power Supplies

Two controllers, one per spacepak, are used to sequence various functions to be performed in the experiments and to record data from analog sensors. It is 65Co2-based microcomputer with 8K RAM, 16K ROM and 32K EPROM. All the programs and all the data collected are stored in EPROM. This same type of controller has been used in several previous GAS payloads of the Utah State University by Professor Rex Megill and his students.
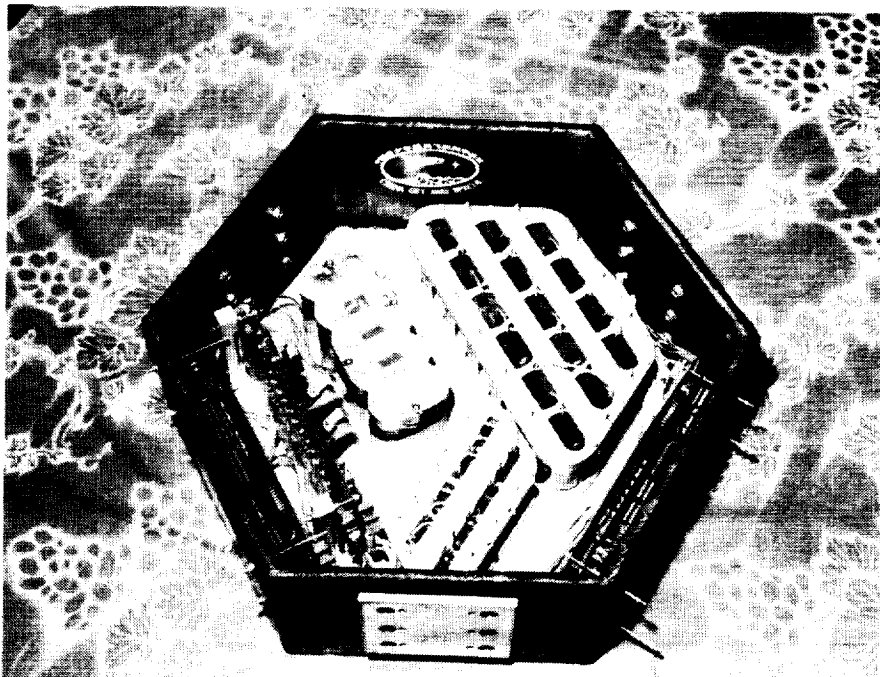
Figure 3. View for experiment #2. Eight small cylinders containing solid mixtures of paraffin and Wood's metal in different ratios and manners are installed under the cover marked by the number 511.

Each spacepak will have two separate power supplies to power the controller and to operate all other electrical devices in the spacepak, including all electronic interface circuitries to the controller. The batteries to be used are rechargeable lead-acid Gates X-cells or D-cells wired in series.

3.5 Operational Scenario

After the shuttle enters the orbit, relay "A" will be turned on at 70,000 feet by a baroswitch automatically. This action sends power to the controller which initiates the controller program sequencing. The controller will wait 2 hours before activating any of the devices in the payload.

In experiment 1, the controller will activate the torque motor to strip off the protective film from the adhesive wall, then the debris will be released and photographed at predetermined time intervals. In experiment 2, the controller will switch on the heater circuits, monitor temperatures and switch them off when the temperature reaches the predetermind value.

4.0 **Development of the Payload**

4.1 Preliminary Design Phase

Both Wang Nian-Qing and Tian Chung-Liang participated actively in the preliminary design phase of their experiments. During the same time period, they have carried out, thanks to the assistance of the scientists and engineers at BIETE, many ground-based preparatory experiments. Those experiments included: heating and melting the mixture of Wood's metal and paraffin by battery power; taking pictures of debris in order to determine the clarity and resolution of the photography; performing test for selected adhesives, etc.. Data collected from those tests helped to guide the design and fabrication of the engineering prototype for the flight model.

4.2 Flight Model Manufacturing Phase

After numerous modifications and iterations of the engineering prototype, the flight model of the payload has been designed and is being fabricated, which includes:

(1) The spacepak and supporting structures for camera, motor and batteries , etc;

(2) The control system, including printed circuit boards and software; ·

7

(3) Foil-type heaters and cylindrical containers;

(4) Assembling;

4.3 Environmental Testing

According to the requirements of experimenter's handbook for GAS payload, environmental testings such as vibration and vacuum thermal test are to be performed on the flight model to demonstrate its compatibility with the space shuttle environments. These tests are in progress and will be completed upon the approval of the phase III Safety Data Package from NASA.

5.0 <u>Acknowledgement</u>

The authors list should include multitude individuals from many Chinese and American sponsoring organizations including, but are not limited to: China Association for Science and Technology, the China Central Television, China Youth News, The China Science and Technology Daily, Science and Technology Center(Los Angeles based), National Association for Chinese American(Los Angeles Chapter) and China Institute of California State University at Northridge. They are indebted to the United Nations for the financial support through the TOKTEN program. They acknowledge Professor Rex Megill of the Utah State University, his colleagues and students for their technical assistance.

Particularly, the authors are profoundly grateful, on behalf of this program, to Dr. Ren Xin-Min and Professor Sun Jia-Dong, of Chinese Ministry of Astronautics, for their unabated support throughout the course of this program.

Finally, the authors would like to express their sincere thanks to countless American and Chinese friends for their encouragement and unselfish support, without which the continued success of this program would not be possible.

I

Development of *BIO-GAS* Systems

M.TAKAYANAGI,[*] S.KITAMURA,[*] H.NEMOTO,[*] T.KIMURA,[*]
Y.ZAIKI,[**] T.KITAKOHJI,[**] S.FUJITA,[***] M.KAMEDA,[***]
M.NODA,[****] Y.KAWASAKI[*****] and A.AJIMINE[******]

[*] FUJITSU Ltd., 1015 Kamikodanaka, Nakahara-ku, Kawasaki, 211 Japan
[**] FUJITSU Laboratories Ltd., 10-1 Morinosato-Wakamiya, Atsugi, 243-01 Japan
[***] SUNTORY Ltd., 1023-1 Yamazaki, Shimamoto-cho, Mishima-gun, Osaka 618, Japan
[****] THE GREEN CROSS Co., 2-1180-1, Shodai-Ohtain, Hirakata, Osaka 573, Japan
[*****] MISTUBISHI-KASEI Institute of Life Siences, 11 Minamiooya, Machida-shi, Tokyo 194, Japan
[******] The Society of Japanese Aerospace Companies, Inc. 1-8-1, Yurakucho, Chiyoda-ku, Tokyo 100, Japan

Abstract

Four experiment systems which have fundamental significances in the field of biotechnology are developed for the Get Away Special(GAS). Unique considerations were necessary to develop the systems which carry out biotechnological experiments under GAS's restricted conditions: - delicate thermal control, fluid handling and protection from contamination. All experimental processes are controlled by internal sequencers and results of the experiments are recorded as images and numerical data within the systems. Our systems are standardized in order to enable repeated use of a variety of experiments by replacement of the experiment modules and modification of experiment sequencing programs.

1. Introduction

Recently, the use of the space environment such as microgravity has been increasingly emphasized. Thermal convection, buoyancy and sedimentation are all strongly affected by gravity and have extremely weak effects in space. Using this phenomenon, high efficiency and purity can be achieved in processing and refinement of materials. This will be most useful in making semiconductors, metallic materials, compound materials, separating and refining medicinal drugs, growing protein crystals and cell culture, for example.

Biotechnology is receiving a great deal of attention with the rapid development of recombinant DNA technology and cellular fusion techniques. Biotechnology is of great significance, not only for its investigations of the phenomena of life, but also for its applications to medicine, agriculture and industry. Space microgravity is also expected to be profitable in this field. We have planned to aproach the space utilization for biotechnology by making use of the opportunity of GAS.

9

2. Experiment Subjects

We have selected four themes fundamental in biotechnology, and have developed four GAS experiment systems corresponding to these themes. These are detailed below.

G-456: Electrophoretic separation of biological materials

In the microgravity of space, the effects of sedimentation, buoyancy and thermal convection, all of which involve differences in specific gravity, will decrease. Therefore, the ability to separate and refine materials by electrophoresis is being studied, particularly in the area of drug manufacture.

In our experiment, a mixture of enzymes will be separated by electrophoresis in a microgravity environment. A laminar flow of buffer solution is created in an electrophoretic separation chamber, and then, the sample is injected. Voltage is then simultaneously applied to electrodes. The phenomina of this separation are observed by a video camera above the separation chamber and recorded by video cassette recorders. The electrode voltages are 100 V, 200 V, and 300 V. Results of this separation will be compared to results obtained on the earth's surface. Fig.1 (a) shows the drawing of the experiment module of G-456.
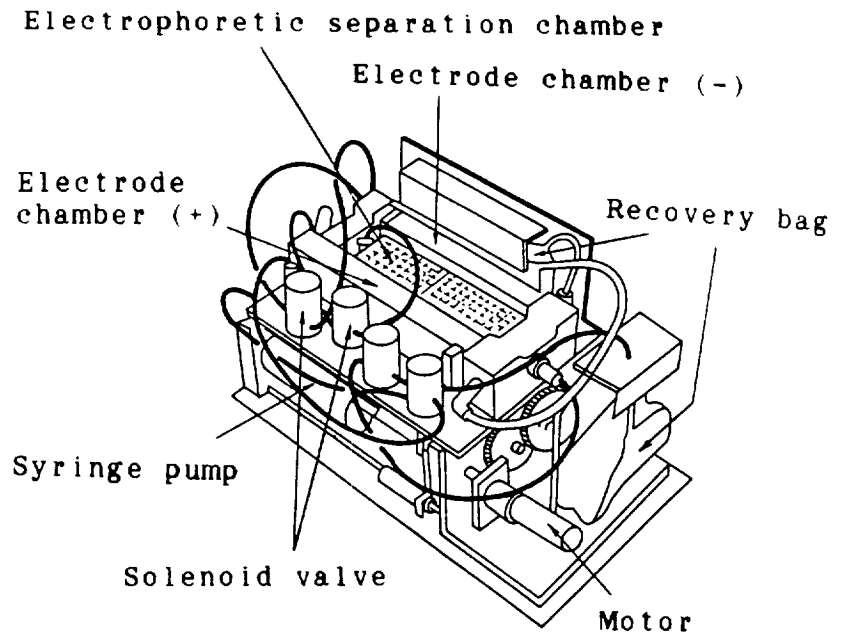
Fig.1 (a) Experiment module of G-456
 - Electrophoretic separation of biological materials
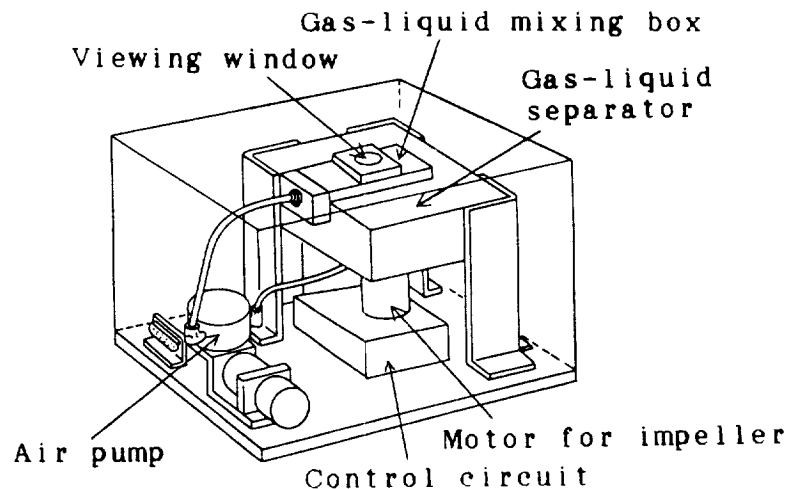
Fig.1 (b) Experiment module of G-457
 - Separation of gas bubbles from liquid

G-457: Separation of gas bubbles from liquid

Culturing and fermentation involve the generation of carbon
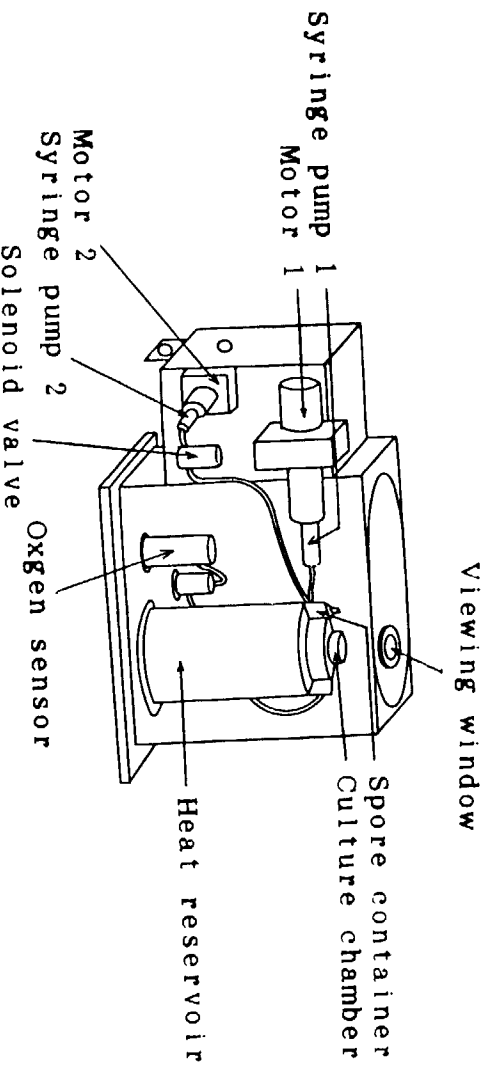
Fig.1 (c) Experiment module of G-458
- Cultivation eellular slime mold

Syringe pump 1
Motor 1
Motor 2
Syringe pump 2
Solenoid valve
Oxgen sensor
Viewing window
Spore container
Culture chamber
Heat reservoir
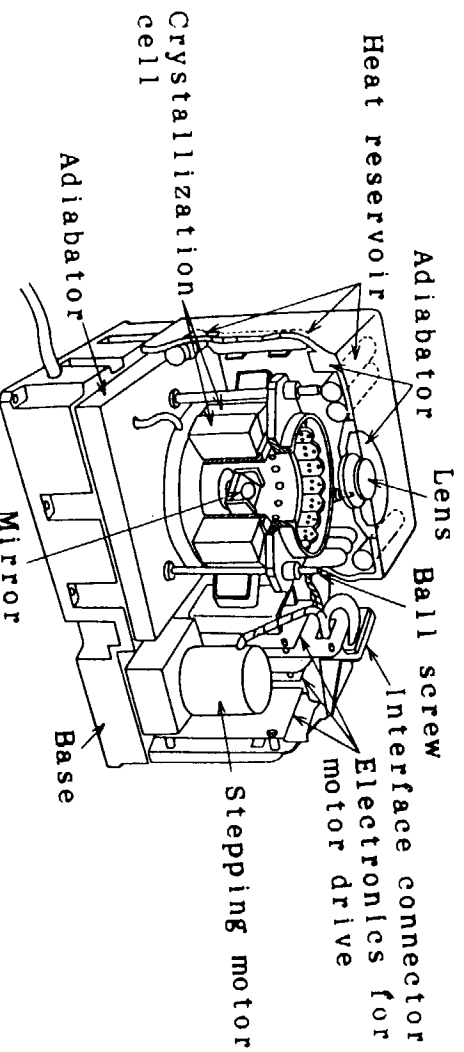
Fig.1 (d) Experiment module of G-459
- Protein crystal growth

Crystallization cell
Heat reservoir
Adiabator
Adiabator
Mirror
Base
Lens
Ball screw
Interface connector
Electronics for motor drive
Stepping motor

dioxide. In a microgravity environment, this gas adheres to living organisms such as yeast and bacteria and the gas interferes with culturing and fermentation, while it can be easily removed from liquid by buoyancy on the earth's surface. Hence, the separating gas from liquid is necessary for culturing and fermentation in space. This technology is related to the development of life-support systems for use in space.

In our experiments, a gas-liquid mixture is placed in a separation chamber. When the blades of the centrifugal separator is rotated, the liquid will gather on the circumference, and gas will collect in the center. The gas in the center will be removed by an air pump, and be injected again into the liquid. The rotating speed of the blades is variable. The movement of bubbles during injection is recorded by a video camera and video cassette recorders to check the separation efficiency. Fig.1 (b) shows the drawing of the

experiment module of G-457.

G-458:   Cultivation of cellular slime molds

Evolution of living organisms has occurred in a 1-G environment, however the relationship between their morphogenesis and gravity is not well known. Cultivation experiments in a microgravity environment will yield data that will help to clarify the function of gravity in the evolution of structure.

In our experiments, the culturing of cellular slime mold in a microgravity environment and its development will be recorded by a 35-mm camera to determine the influence of gravity on structure at the cellular-molecular level. We use airtight experiment module with an air atmosphere. Agar is placed in the culture tank, and mixture of water and spores, is prepared separately. Spore culturing begins with the injection of this mixture into the culture tank. Fig.1 (c) shows the drawing of the experiment module of G-458.

G-459:   Protein crystal growth

Convection and sedimentation are weakened in microgravitational conditions. It is thus expected that large, high-quality protein crystals can be obtained in microgravity, then they can be used for 3-dimensional X-ray diffraction analysis. This will help contribute to protein engineering.

The G-459 system has 16 crystallization cells and protein crystals will be grown in microgravity in each cell. The growth will be photographed by a 35-mm camera. The protein crystallization cells are designed for the spontaneous mixing of an ammonium sulfate solution and a protein solution by removing a partition. This experiment will be done using three different methods: batch, free surface diffusion and vapor diffusion. Fig.1 (d) shows the drawing of the experiment module of G-459.

3. System Outline

Concepts

In the development of our experiment systems, the following was considered:
1) Standardization of system is needed to enable repeated use for various kinds of experiments. Electrical subsystems and structures were designed to allow standard use.
2) All experiment systems must conform to the safety and interface requirements for the Space Shuttle established by NASA.
3) All controls, other than turning on of an electrical power source, which is made by a baroswitch, must be done automatically by a sequencer in the system.
4) Results of the experiment must be recorded within the system as images and numerical data. These data will be recovered and analyzed after the return of the Shuttle.
5) Commercially produced components were used as much as possible. However, modifications such as mechanical reinforcement must be made to ensure that NASA's environmental durability requirements are met.

12

Design of Subsystems

Each experiment system consists of the speciallized experiment module and other subsystems which are common for all four systems such as electronics subsystems containing the experiment controllers, recorders and an alarm, a battery assembly and support structures. Fig.2 shows the photograph of the G-459 system. Other three systems have the same configurations.

The experiment systems can be divided into two groups, by the difference in their applicable experiment durations. The G-456 and G-457 have experiment durations of about 30 minutes, and have a relatively small battery capacity, 600 W-hours. Image data of these experiments are recorded by video cassette recorders. The G-458 and G-459 have durations of about 120 hours. For these, the battery capacity is 900 W-hours, and images are recorded by a 35-mm camera. Except for these differences, our experiment systems are standardized as much as possible. Researchers can select the most appropriate system type for their experiment. Fig.3 is a block diagram of the G-459 system, which is common to all four systems except for image observing and recording subsystem. Common design
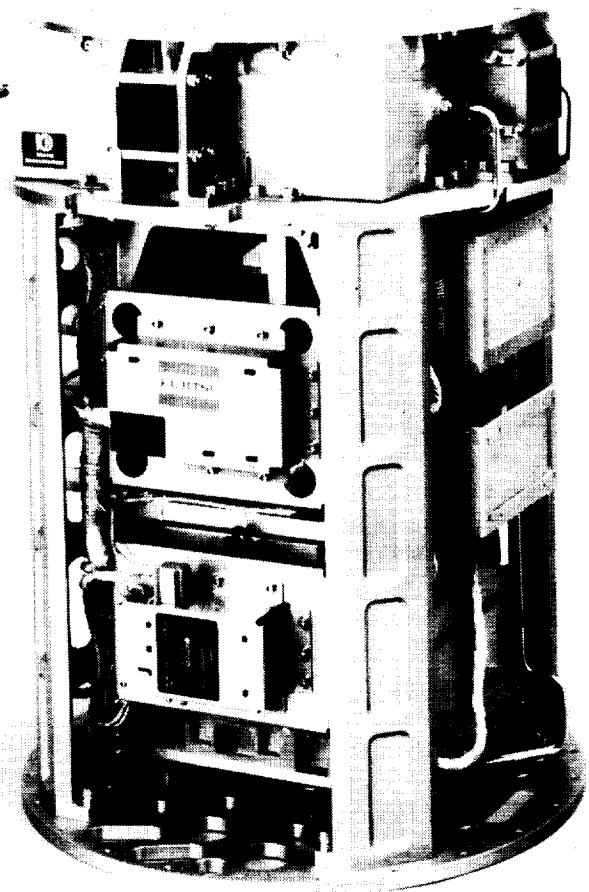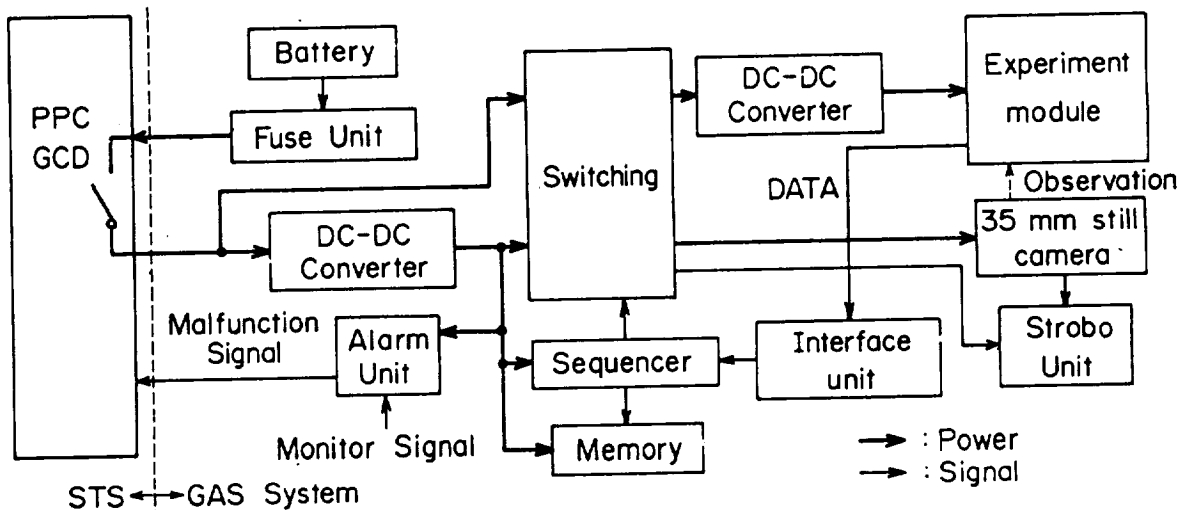

Fig.2 G-459 system

Fig.3 Block diagram of the G-459 system

13

features are explained below.
1) Subsystems for Experiment Control

For automatic experiment sequencing and for repeating experiments, an 8-bit CMOS microprocessor which consumes little electricity and a PROM are used. The experimental sequence can be changed easily by modifying the program on the PROM.

2) Subsystems for Data Recording

The G-456 and G-457 use a combination of a video camera and video cassette recorders, and the G-458 and G-459 use a 35-mm camera for recording the image data of experiments. The video cameras used have solid-state image sensors and are reliable and environmental resistant. We use two portable video cassette recorders for each system as one for redundancy. All recording equipment have been structurally reinforced.

Power source voltage, container temperature and each subsystem's temperature and voltage supplied to each subsystem are recorded in EEPROMs. In case for G-456 and G-457, they are also recorded on the audio channel of video tape. If these data exceeds the predefined ranges, an alarm signal will be transmitted to the Shuttle. The system's main switch will be shut off by this signal.

3) Power supply

We selected lead-acid storage batteries made by the Gates Co., for power source. For the G-456 and G-457 systems, the battery assembly has a total capacity of 12.0 V x 50 A-hours (= 600 W-hours) with 24 cells and G-458 and G-459 have 12.0 V x 75 A-hours (= 900 W-hours) with 18 cells. Fuses and diodes are installed for safety measures. Diodes are installed in each series unit of battery cells to prevent current reversals between the battery cells.

DC/DC converters convert and stabilizes the 12-V source power from the batteries and they supply the electricity to each subsystem.

4) Support structure

We used shelves-supported-by-struts structure for our experiment systems (see Fig. 2). This kind of construction is one of recommendations of NASA.

Two discs and four supporting struts are assembled rigidly. All these components are made of aluminum alloy A7075 and A5052. The camera and electronics are mounted on support struts or between struts. Batteries are mounted on the top disc between the lateral supports. The experiment module is mounted on a stand attached to the bottom plate.

Holes for mounting screws are drilled in the supporting struts and in the discs at each constant distance. Position tuning mechanism for the camera is included in its support. These considerations enable standardized use of our systems.

4. Special Considerations for Biotechnological Experiments with GAS

There are many restrictions on the GAS payload. Among them, waiting period for launch of more than two months was most crucial for our systems because delicate biological matters, living organisms and fluids are needed in biotechnological experiments. In such restricted condition, it is difficult to develop a system for carrying out a significant space experiment, especially a biotechnological experiment. Actually, there have been very few

14

successful biological experiments (Ref. 1). Special considerations are therefore needed as follows.

Thermal control

For our experiment systems, we will use insulated end caps and we have requested the passive thermal control (PTC) mode for the Shuttle flight. In this flight mode, the Shuttle rotates around its X-axis to keep the temperature as constant as possible so temperatures within the GAS container fluctuate between 0 C and 40 C in case that the power consumption within the container is below 30 W (Ref. 2). This temperature fluctuation is quite small for space, but is large for experiments whose contents are liquids and biological samples. For example, the liquids cannot be allowed to freeze. Furthermore, if the temperature in the experiment module of G-468 drops below 17 C, the growth of the cellular slime mold is inhibited and if the temperature rises above 27 C, the cellular slime mold is killed. In the G-459, the most efficient temperature for the growth of protein crystals will be room temperature, but this varies with the type of protein used.

Because of battery limitations, we use passive methods for thermal control using heat insulators, heat reservoirs and antifreeze. According to experimental requirements for thermal control, we have carefully selected materials and their compositions for these thermal control methods. It was confirmed by environmental tests that thermal controls of sufficient quality have been achieved for all systems.

Handling of fluids

All systems contain fluids. Leakage, evaporation, and bubble formation must be avoided. Measures must also take the approximately two-month waiting period into consideration. To avoid above problems during this two-mouth period, we have been with great care for materials for sealing, designing containers for liquids and method for sealing. For example, water diffuses through acrylic resin containers and silicon rubber packing, so they cannot provide a perfect seal for two month. We therefore used "Viton" packing and a special less permeable resin. We have conducted long-term tests and confirmed their durability for preservation.

Contamination

Protein, slime mold and culture mediums for biological substances are used in all experiments except for the G-456. Therefore, if other bacteria mix with an experiment system, problems of metaplasia and putrefaction will occur during the waiting period. Therefore, containers and transportation tubes that hold these substances are designed so that they can be sterilized. They are also designed so that they can be assembled apart from other mechanical sections.

5. Concluding Remarks

Production of the four biotechnological space exberiment systems for the GAS have been completed (Fig.2). Tests of operation and durability for envirouments such as temperature and vibration were also conducted successfully. We have obtained significant results of ground experiments which will be compared with the result of experiments carried out in space. Some of these results are shown in Fujita et al.(Ref.3). Other than these four systems for biological experiments, we have also developed a GAS system for the crystallization experiment of compound semiconductor materials (GaAs and PbSnTe) which is shown in Ref.4. We hope early launching of our systems soon after the resumption of the Shuttle flight program.

The possibilities for utilization of the space environment are virtually unlimited and many nations have space programs. To encourage major projects, accumulating as much basic data and experiences as possible is of great importance. GAS can easily achieve these goals. Our four experiment systems introduced here are not only significant in biotechnology, but can be adjusted and used for experiments in other fields. We expect these systems will be able to meet future demands to make use of GAS as well as the success of these four experiments.

Acknowledgement

References

1. R. W. Ridenoure, "A System-level Performance History of Get Away Special after 25 Space Shuttle Missions," Proc. of 1986 Get Away Special Experimenter's Symposium, pp.79-86, NASA Conference Publication 2438, GSFC, 1986.
2. GAS Experimenters Handbook, GSFC Special Payload Division, 1987.
3. Fujita, S., K. Asano, T. Hashitani, T.Kitakoji, H.Nomoto and S.Kitamura, "Protein-Crystal Growth Experiment (Planned)" Proc. of 1987 Get Away Special Experimenter's Symposium, pp.63-68, NASA Conference Publication 2438, GSFC, 1987.
4. Kitamura, S., H.Nemoto and S.Kodama, "Development of GAS Small Self-Contained Payload," FUJITSU. Vol.38, 1, pp.57-66 (1987) (in Japanese)

GAS EXPERIMENTERS SYMPOSIUM

SEPTEMBER 27-30, 1988

TUBSAT-1, SATELLITE TECHNOLOGY FOR

EDUCATIONAL PURPOSES

A. Ginati

Institute of Aeronautics and Astronautics
Department of Satellite Design and Technology
Technical University of Berlin, W.Germany

Abstract

TUBSAT-1 (Technical University Berlin Satellite) is an experimental low-cost satellite within the NASA GAS (Get Away Special) program.

This project is being financed by the German BMFT (Federal Ministry for Research and Technology, mainly for student education. The dimension and weight are determind by GAS requirement and it will be ejected from the space shuttle into an approx. 300 km circular orbit. It is a sun/star oriented satellite with an additional spin stabilisation mode. The first planned payload is to be used for observing flight paths of migratory birds from northern Europe to southern Africa and back.

Introduction

It was a big challenge for the students to design and develope a low-cost experimental platform which enable a rather precise orientation in orbit. GAS program provides a low-cost with high launch frequencies, so that the students can complete their own experiments in the short study period.

It was leading to the development of the GAS compatible satellite of the Technical University Berlin (Fig. 1). More than 50% of its volume is planned for useful experiments like navigation (white storks) equipment and components for space application (star sensor, GaAS solar cells), store forwards communication (mail-box), observation (CCD-chip camera).

The cooperation with MBB (Messerschmidt Bölkow Blohm) in this project is important in order to provide exchange between space industry and the university. Some of TUBSAT-1 subsystem and ground segment have been tested already using the flight opportunity of MIKROBA (OHB-SYSTEM project, supported by BMFT) in Esrange, Sweden in April 88.

Fig. 1 TUBSAT-1
main component:

 - FMW
 - OBDH + TM/TC
 - star-sensor
 - magnetic rod
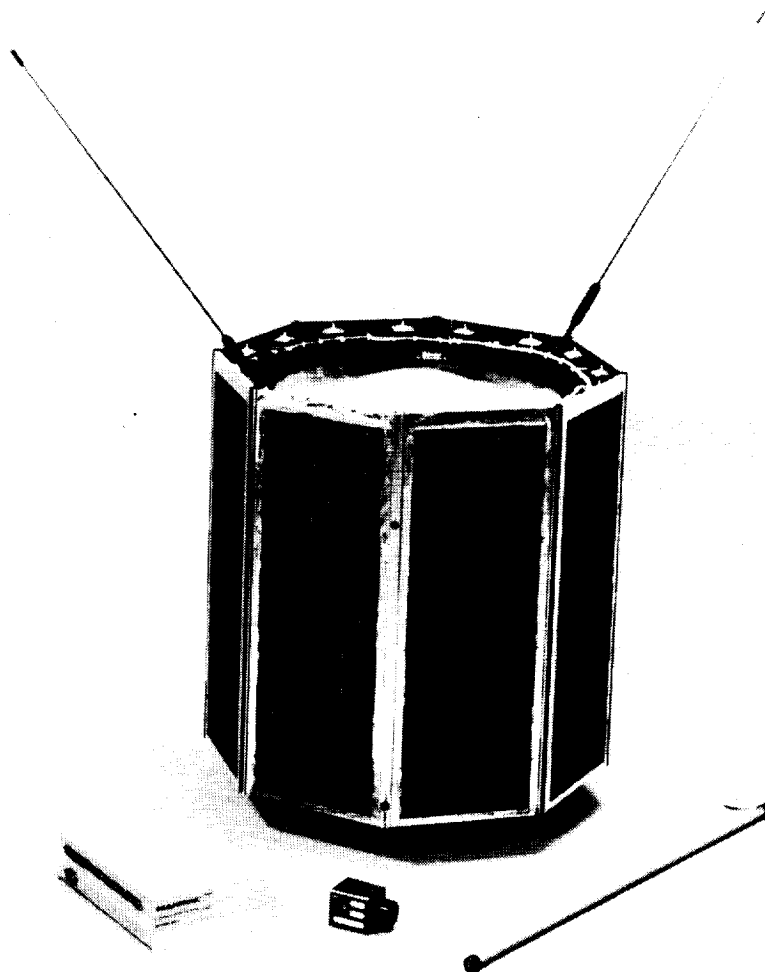
Mechanical Structure

The mechanical structure of TUBSAT-1 (fig. 7) consists of two ma-
jor components, a central structure and outer shell.
The central structure is composed of two crosswise mounted sand-
wich plates, an octagonal shaped sandwich plate mounted at the top,
and an adapter ring is placed at the bottom. The central structure
provides rigid support to mount all TUBSAT equipment. The adapter
ring has been designed for compatibility with the marman plate of
the GAS ejection mechanism.

The outer shell is composed of eight panels and eight supporting
struts. The panels provide support for the solar array. The struts
interconnect the solar panel to the central structure, so that the
outer shell can be easily dismounted from the central structure to
ensure accessibility to all components.

The main parts of the structure are considered in strength verifi-
cation analysis, using a detailed finite element model to calculate
accurate forces and stresses with respect to the GAS payload safety
requirements. It is to state that all parts are covered with posi-
tive margin of safety.

Mass distribution:

- structure and interface ring	5.33	kg
- solar panel	4.02	kg
- fixed momentum wheel	7.60	kg
- batteries	3.84	kg
- electronics	3.21	kg
- TM/TC + OBDH	2.00	kg
- torque rods	6.00	kg
- payload	36.00	kg
total	68.00	kg

On bord data handling subsystem (OBDH)

The on bord data handling subsystem (Fig. 2) manages and coordinates all subsystem and experiments. It is based on Hitachi (HD 63701 XO) 8 bit CMOS single chip microcomputer unit (IC1) which contains 4k bytes of EPROM and 192 bytes of RAM. If excess information is to be stored, the included external 32 k bytes RAM (IC3) can be used. It also contains an analogue/digital converter (IC2) with 16 analogue inputs. The buffer (IC4) is used for the interface to the TM/TC subsystem. Additional serial interface are provided for the attitude control subsystem and for three different experiments. They all should have their own microcomputer to enable efficient communication. The "watch-dog-timer" (IC5,6) listens carefully every 65 ms to the heart pulse of the computer, in case of a heart attack (no pulse after 100 ms) shock therapy follows immediatly through resetting.
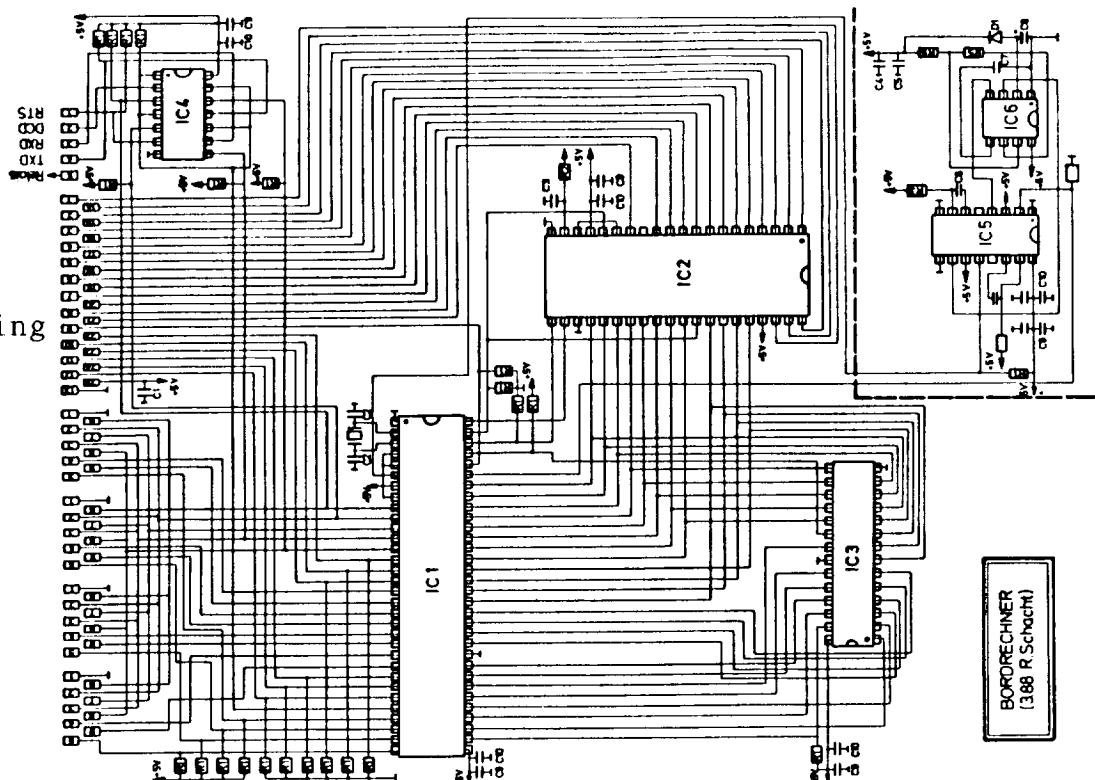
Fig. 2
On bord
data handing
subsystem

Thermal analysis

The successful operation of the battery, electronic equipment and payloads, requires a fairly close control of the temperature to which it is subjected. Even though it is a disadvantage from a thermal point of view to spread out the batteries around the momentum wheel, it has been done mainly for space optimisation reasons.

For the transient orbital temperature analysis, the TUBSAT orbit data have been assumed, taking into consideration the albedo, solar and earth source of radiation, and the dissipation power of the satellite equipment. One node model has been developed, it consists of 59 nodes with different heat rate input according to the three attitude modes.

A: 3-axes stabilised (solar panel edge pointed to the sun)
B: "   "   "   "   surface "   "   "   "
C: spin stabilised

By using multilayer insulation (MLI) on the top and bottom of the structure, black painted equipment on the inside area, and white painted outside surfaces (Fig. 3).

100 orbit cycles were repeated in order to obtain an exactly permanent periodic state. In all three calculated attitude modes, the analysis has shown a possible operating temperature range as follows.

temp. °C/ mode	battery min	max	electronics min	max	solararray min	max
A	11	32	3	36	-33	64
B	9	31	0	28,5	-35	67
C	16,7	13,6	5	25	-24	32

Fig. 3
Radiative properties in the node model

$\alpha = 0.56$ } P-cloth
$\varepsilon = 0.85$ }

$\varepsilon_{eff} = 0.019$ MLI

$\varepsilon = 0.7$ MLI (capton)

$\varepsilon = 0.9$ Black coat.

$\bar{\alpha} = 0.65$ } solor
$\varepsilon = 0.82$ } cels

MLI

$\alpha = 0.3$ } white
$\varepsilon = 0.9$ } coating
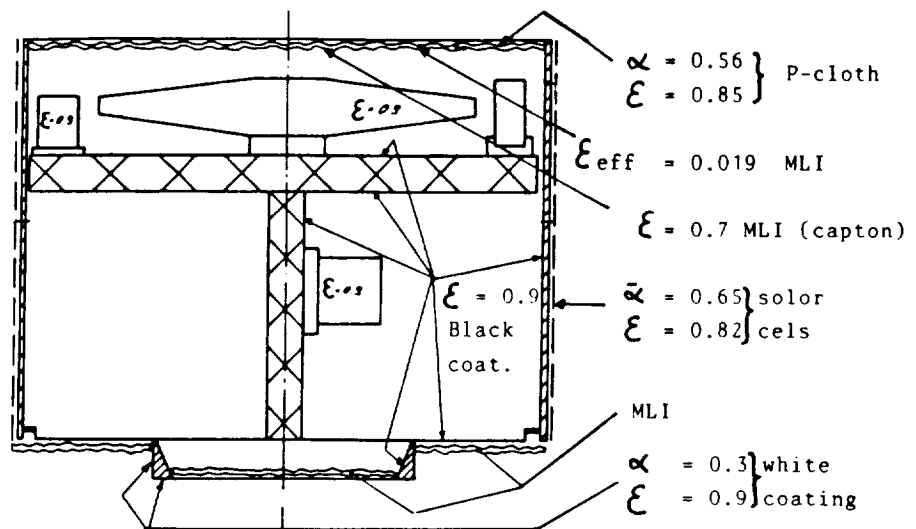
Power Subsystem

From examination of the mission profils, it is apperent that the solar generated power has a wide voltage variation, therefore it is necessary to provide good battery management to control and optimize the charge function of the battery. A maximum number of 49 solar cells of the type k7000 Spectrolabe (62.1x20.9 mm) can be attached to each of the eight panel. Matching process of all 392 cells have been done, considering the working point voltage of 23.5 V for each solar panel. This value is based on the maximum charge voltage available of the chosen batteries. So that each panel supplies an average current of 535 mA, almost the same power (12.65 W at 28° C) and 32 W (28° C) when light striks perpendicular to the pitch axis.
In the spin mode according to the thermal analysis the average temperatur of the arrays is less than 28° C so that a power increase is expected. In the 3-axes mode, a power drop of 40% from the panel facing the sun (60° C array temperature) is expected.
The battery system consists of a string of 16 Nickel-Cadmium cells each 7Ah, 1.47 V (VR7 SAFT). Assuming a 90 minute orbit with a 38 minute exlips time, a power supply of 32 W, with 75% of battery efficiency it would yield 17 W (23.5 V/0.72 A) available power consumption. This means, that the 15 W battery required charge power (charge rate of 0.1 C = 0.7 A), is in the safety margin. The 3-axes mode electronic includes step-up converter for each panel to increase the supply voltage to the proper charge value.
In the spin mode the shunt regulator uses a cell temperature signal to avoid battery overcharge, or "allowing" colder cells a full charge (Fig. 4).
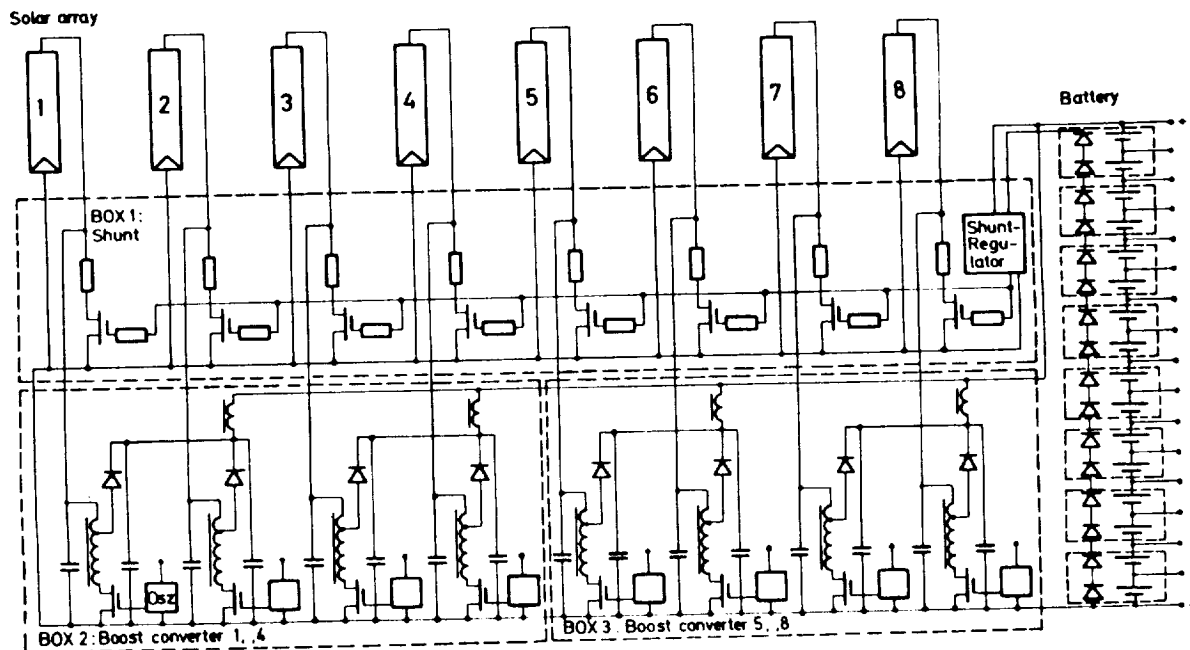

Fig. 4 Power subsystem

21

Attitude control and stabilisation subsystem

The attitude control and stabilisation subsystem (ACS) consists
of a fixed momentum wheel (FMW,50nms,Teldix), magnetic rods, sun-,
star- and geomagnetic field sensors (Fig. 6).
Two attitude modes are designed, spin and 3-axes stabilisation at
momentum vector perpendicular to the sun. The additional possibili-
ties of pointing this vector in any other direction will be tested
later on. The ACS concept based on microcomputer unit (MCU) with
additional A/D and D/A converters in order to collect and distri-
bute signals for maintaining the required position with respect to
any error signal. The star sensor has two working modes, differen-
ciation mode, where every picture is compared to the previous one,
and integration mode, where each new picture is being compared to
the first one only.
The magnetic rods are used for dump nutation, wheel desatoration
and presessing the momentum vector.
Here it is important to mention that the FMW used for the attitude
stabilisation should be run up shortly before the satellite will be
ejected. This matter has already been discussed in October 1986
with the GAS payload officer.

Telemetry and telecommand subsystem (TM/TC)

Using commercial components with minimum power consumption were the
main requirements for design and development of the modem (modula-
tor/demodulator, Fig. 5) and transverter. FM modulation has been
chosen, with a bit rate of 400 baud. This value can be changed easi-
ly on demand through replacing only 2 resistors (increasing the
bandwidth of the appropriate filters). To achieve a compact system,
the request to send signals (RTS) is used to change the switch po-
sition (receive/transmit), so that the essential part of the system
works for transmitting and receiving too. The receiving signal
(29 MHz) is being mixed twice to 455 KHz (IC1,2). Variable control
oszillator (VCD) compensates the Doppler effect and possible shif-
ting of the other oszillators. The subcarrier frequencies are at
1300/2100 Hz.

Fig. 5
Modem
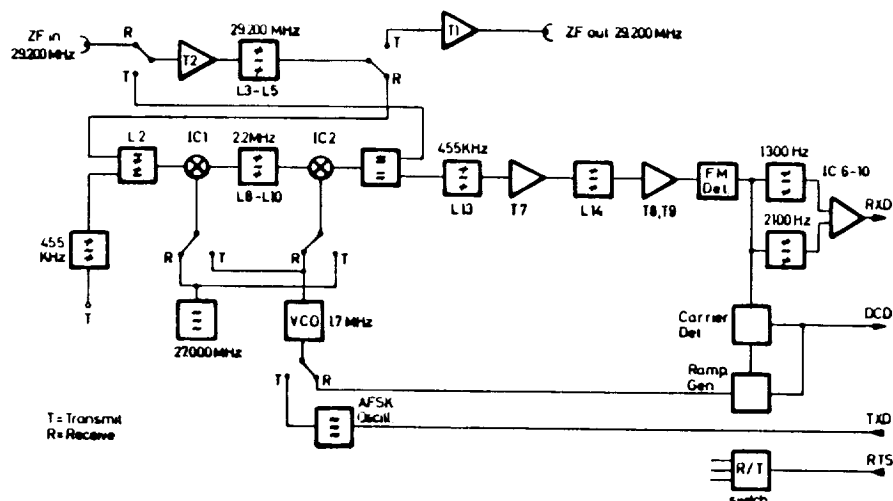
2m - 10m transverter mixes and amplifies the modem output signal to the current TM frequencies of 137.8 MHz, 0.1 W power, and vice versa when receiving the 148.1 MHz uplink signal.

Ground station

With orbit inclination of 57° TUBSAT-1 will be controlled by the main ground station, which is placed at the Technical University of Berlin, in case of lower orbit inclination, the already existing portable ground station can be placed anywhere in the mediterranien countries to enable contact.

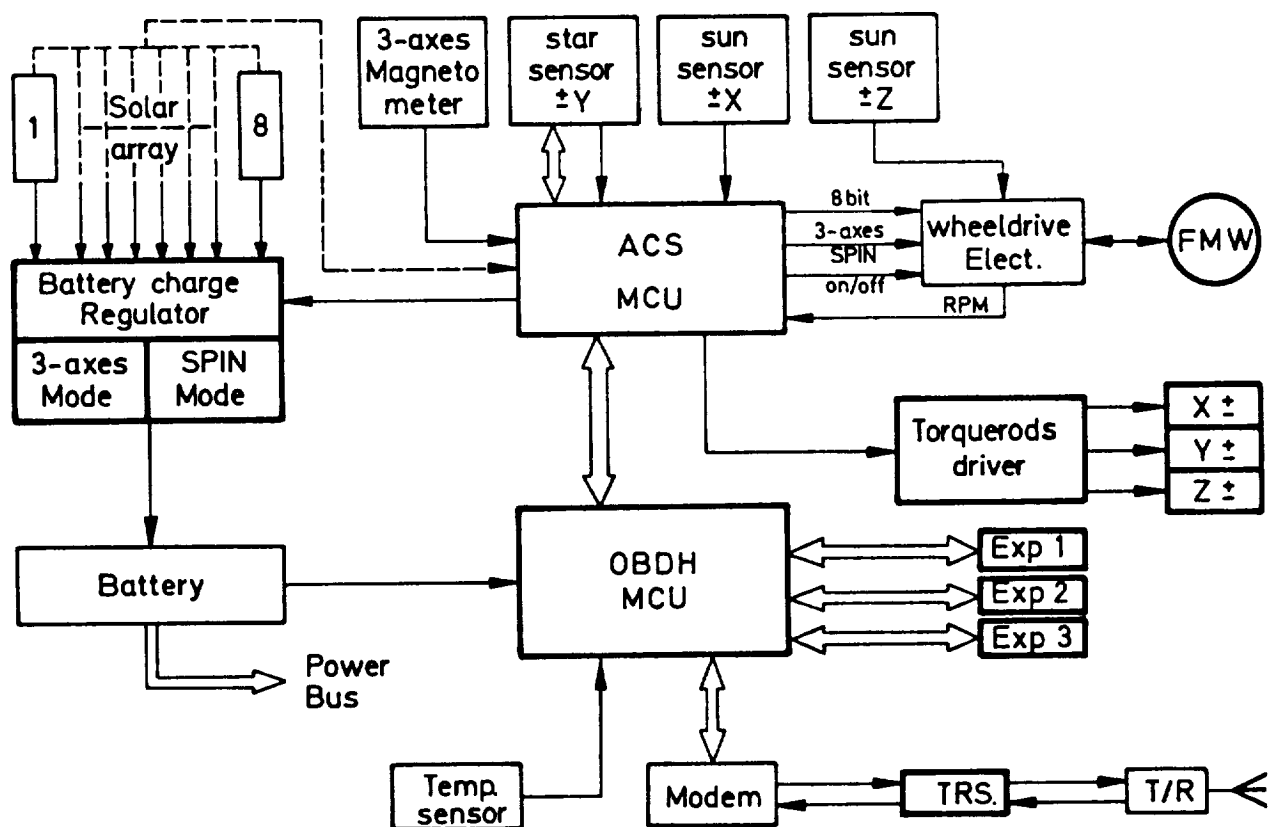All ground stations are similar and use the same communication terminals as on board, with only different extensions.
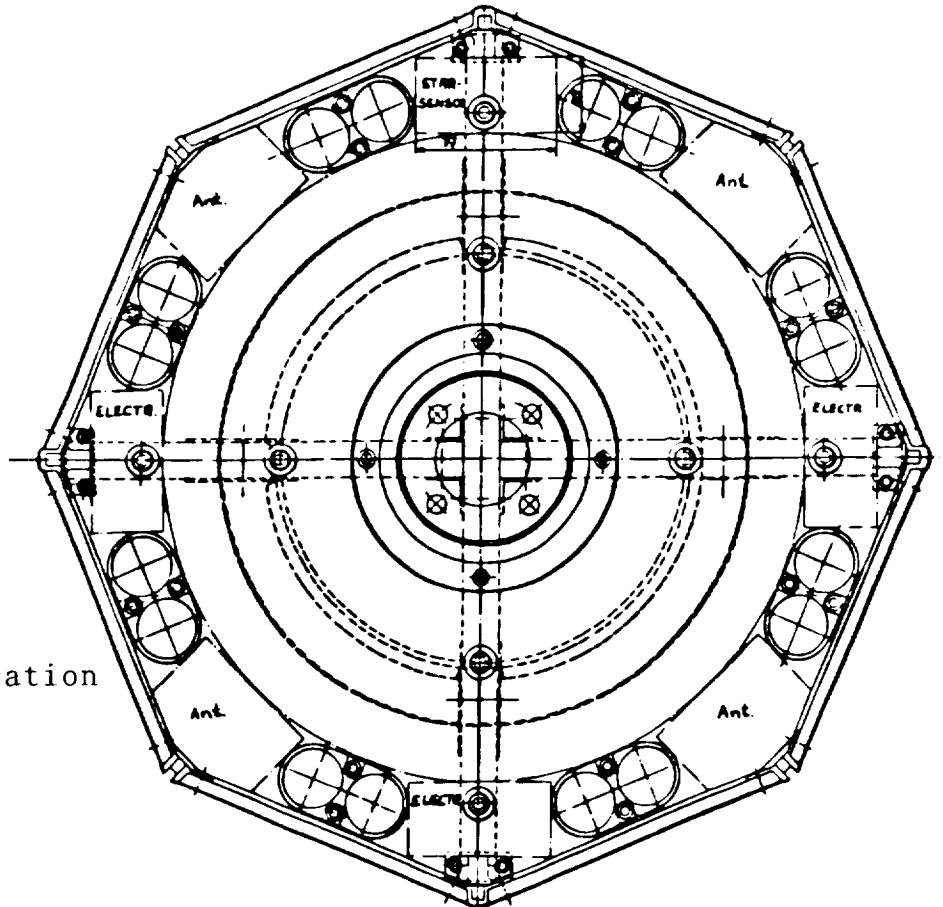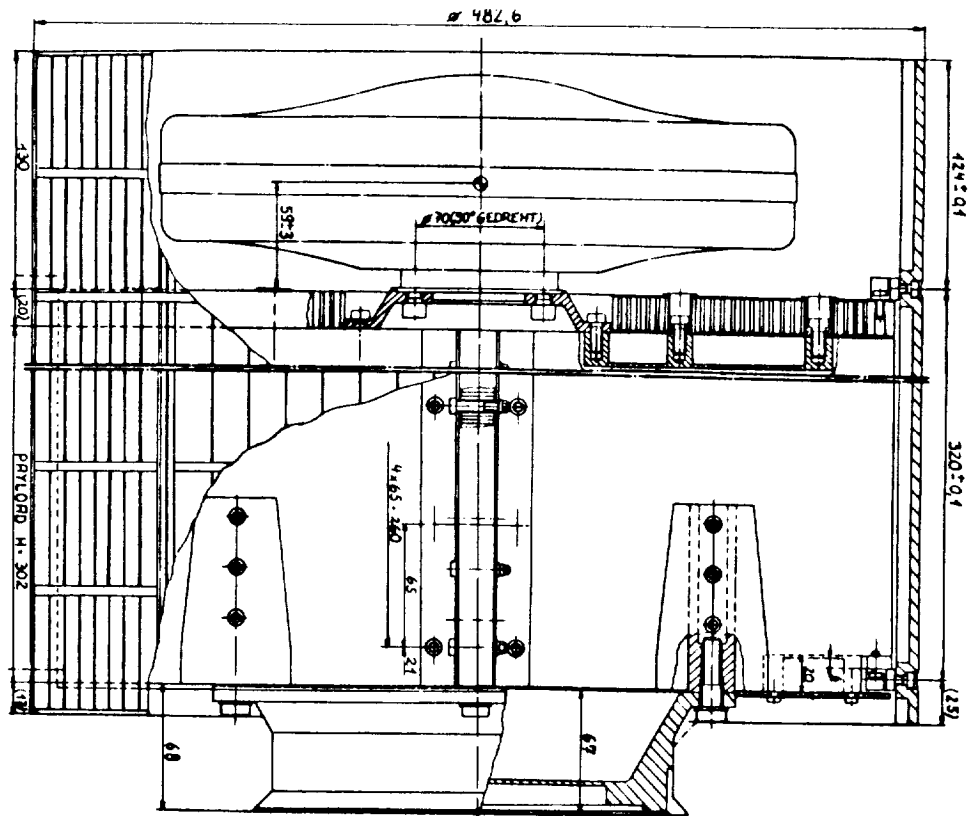
Fig. 6 TUBSAT-system diagram

Fig. 7
TUBSAT-1
configuration

Dr. S. Staniek, Dr. G. Otto, DFVLR, D-5000 Köln 90
Dr. J. Döpkens, MBB-ERNO, D-2800 Bremen 1, FRG

FUTURE MAUS PAYLOAD AND THE TWIN-MAUS CONFIGURATION

Abstract

The German MAUS project was initiated in 1979 for optimum utilization of NASA's Get-Away-Special (GAS) program. The MAUS standard system has been developed to meet the NASA requirements for flying in Get-Away-Special containers. MAUS can accommodate a wide variety of GAS-type experiments, and offers a range of services to experimenters within a framework of standardized interfaces.

Currently, four MAUS payloads are being prepared for future Space Shuttle flight opportunities, and are described in this paper. The experiments include critical Marangoni convection, oscillatory Marangoni convection, pool boiling, and gas bubbles in glass melts. Two of them are reflights with modified scientific objectives, and the other two are new experiments. Scientific objectives as well as experiment hardware will be presented together with recent improvements to the MAUS standard system, e.g. new experiment control and data management unit and a semiconductor memory.

A promising means of increasing resources in the field of GAS-experiments is the interconnection of GAS containers. This important feature to meet the challenge of future advanced payloads has recently been studied. In the TWIN-MAUS configuration, electrical power and data will be transferred between two containers mounted adjacent to each other.

1. Scientific Objectives

The experiments in preparation are from the area of materials science and the results will improve the understanding of selected basic microgravity phenomena (Ref. 1).

The complex features of Marangoni convection will be further elucidated by two separate experiments. The objectives are as follows: documentation of the influence of iso-rotation on the steady and oscillatory state of convection, evaluation of the shape stability of the floating zone configuration during rotation, determination of the influence of higher Marangoni numbers on the hydrodynamic stability by variation of the temperature gradient. Convection is made visible in silicone oil by dispersed Al_2O_3 particles.

In a reflight of a previous successful MAUS experiment the onset of oscillatory Marangoni convection in sodium nitrate is further investigated. The frequency spectrum at higher Marangoni numbers with different aspect ratio will be measured and analysed to describe the transition to turbulence. In ground-based and flight experiments the Prandtl number, the aspect ratio and the gravity influence are varied systematically.

Pool Boiling (nucleate boiling) and forced convection are the most effective heat transfer mechanisms. From the many fluid physics phenomena which are observed in boiling, kinetic heat and mass transport by evaporation and condensation is independent of gravity. This experiment will lead to a physical separation of the gravity driven parameters and trence to a better understanding of the boiling process.

Fining is one of the most important processes in technical glass fabrication. The removal of gas bubbles from glass melts can be achieved in two ways: rising of the bubbles caused by buoyancy (which does not occur in microgravity) and dissolution diffusion. The shrinking of a He-bubble at around 1100°C was successfully recorded in a previous MAUS experiment. This investigation will be performed at the higher temperature of 1300°C to complement data on the diffusion in a wider temperature range. The convectional influence is expected to be stronger, and a larger difference between terrestial and space experiments because of reduced viscosity will result.

2. Experiment Hardware

In MAUS experiment DG 302 thermal Marangoni convection in a floating zone is initiated by an axial temperature gradient along a free surface.
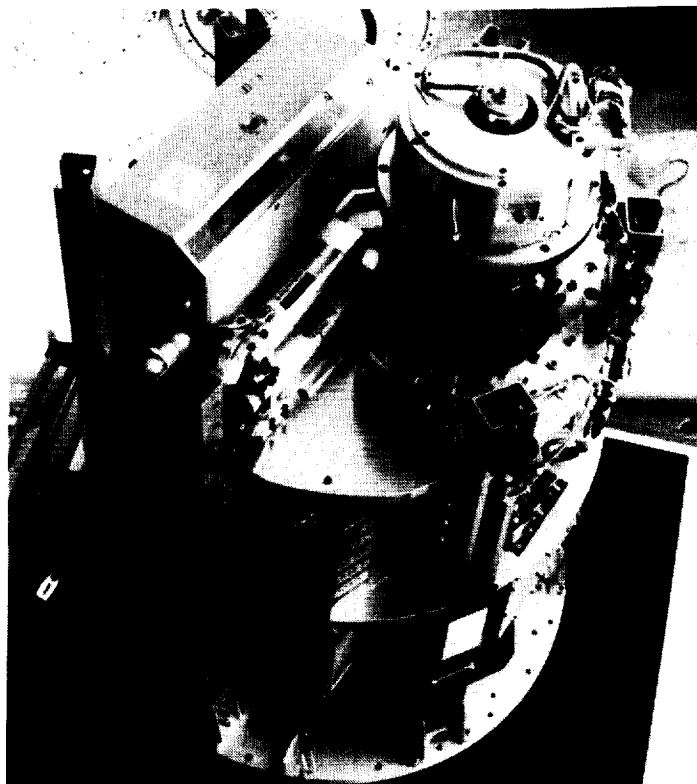
Fig. 2-1: MAUS-Payload DG 302

A cylindrical floating zone is formed between two coaxial discs which can individually be rotated by two electric motors. The discs are in contact with each other before the silicone oil is injected by retracting one of the discs. The test liquid enters into the gap between the two discs through a central hole in the the retracting disc. At any axial location, sufficient test liquid is injected to form a cylindrical floating zone.

Convection is made visible by small particles dispersed in the silicone oil. An optical plane generated by a He-Ne Laser assembly illuminates the particles on the meridian plane of the floating zone. This "light-section" technique enables motion pictures of two dimensional velocity components to be taken. The resulting film will show the onset of the Marangoni convection phenomenon, and the mass transport effects which it causes.
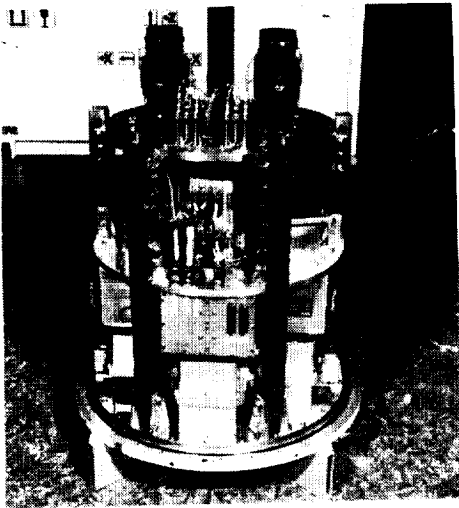
Fig. 2-2: MAUS-Payload DG 321

In MAUS experiment DG 321 two experiment chambers with zones of different length are mounted on the upper experiment platform and operated simultaneously . The floating zone is established by melting a solid $NaNO_3$-cylinder between two graphite pistons. The liquid zone is held in position by surface tension forces. The graphite pistons are screwed into resistance heaters mounted in the housing of the hermetically sealed experiment chambers.

Thermocouples are used to control the temperatures of the heaters and of the pistons. A second thermocouple records the temperature oscillations in the liquid zone. The signals of the thermocouples as well as the heater currents are fed to the MAUS data acquisition system.

MAUS-Payload DG 504 has been described in detail during the 1987 GAS Symposium, (Ref. 2) therefore only the experiment cell is presented here.
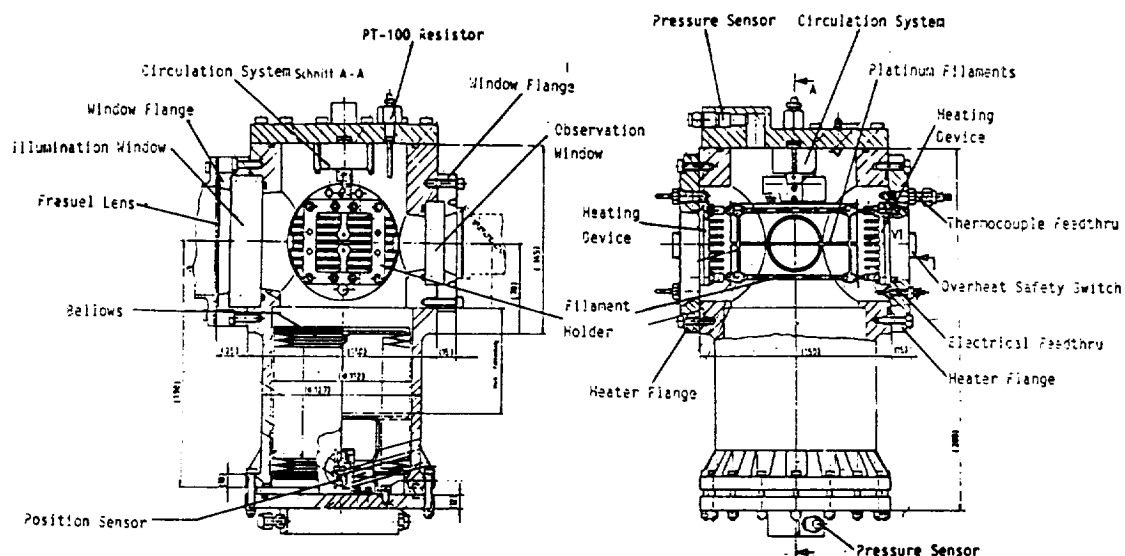
Fig. 2-3: Experiment Cell DG 504

A test liquid Freon R12 is contained in the experiment cell the basic geometry of which is a cube, having three cylindrical hollow spaces perpendicular to each other. Each of them is closed by two opposite flanges. A cylindrical extension contains a bellows which can be filled with nitrogen gas to achieve the desired pressure values. Windows on opposite sides of the cube allow for illumination and optical observation. Two heating devices are installed on the inside of the remaining two opposite flanges. Additionally, the liquid can also be circulated by a rotating paddle mounted on the upper flange. Two platinum filaments are mounted on an exchangeable filament holder. Eight thermocouples provide for temperature monitoring capability at different locations within the experiment cell. The Freon temperature is measured and controlled by a PT-100 sensor. The pressure of the nitrogen gas and of the Freon will both be monitored and controlled by piezoresistive absolute pressure transducers. To prevent overheating an overheat safety switch is mounted in good thermal contact on each of the heater flanges.

Other subsystems needed to operate this payload are the Freon expansion container, the pressure system, the optical system, and the interface electronics.

MAUS experiment DG 324 will be carried out to expand the data of experiment DG 318, successfully performed on STS-11. The same experiment configuration will be used, but with a different experiment profile (higher temperature, longer duration). The cylindrical glass sample (74 SiO_2 16 CaO - 10 Na_2O) with an artifical helium bubble at its center is held by a platinum tube which is closed by transparent sapphire win s. The furnace has an opening at either end, one for illuminating the bubble by a flashlight and the other for taking photographs.

The temperature of the sample will reach 1300°C during operation. A thermal analysis showed that only the integration of heatpipes can provide the needed heat flux to achieve a reasonable temperature distribution within the container.
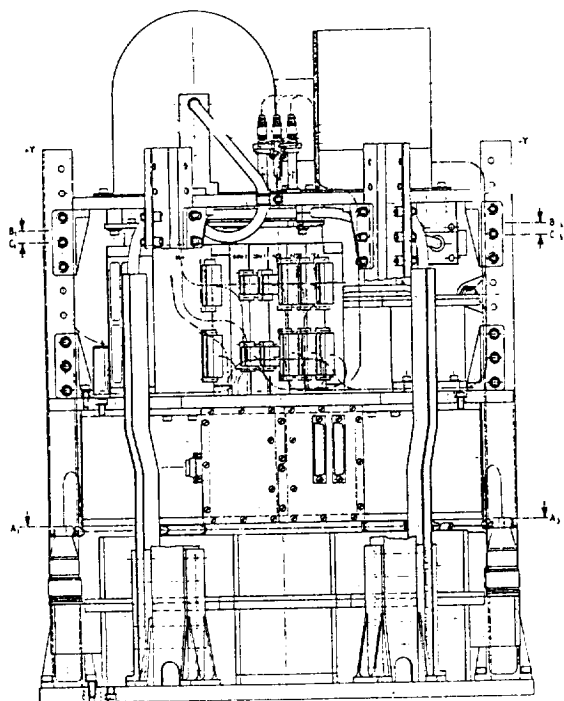
Fig. 2-4: MAUS-Payload DG 324 with Heatpipes

Three heat pipes are directly coupled to the upper experiment platform on which the furnace is mounted. The opposite ends of the heatpipes are screwed to the brackets which connect the posts to the adapter ring. These modified brackets provide a larger contact area to the heatpipes as well as to the adapter ring, and assure adequate thermal conductance to the GAS container top plate, from which the heat will be radiated to space.

3. Improvements to the MAUS Standard System

The hitherto existing standard electronics for experiment control and data acquisition were developed almost ten years ago, but are now out-of-date and no longer suit the requirements of the experimenters, especially considering data resolution (10 bit) and data evaluation (Ref. 3). Four units of a new experiment control and data management system, based on an existing MBB-ERNO design, will be available to the MAUS project this year. To avoid changes in the existing experiment accommodation the modules will be housed in the existing casing. In its basic configuration the system will only consist of three modules, two for experiment control and data acquisition, and one for data storage. Additionally, a dc/dc converter replacing the electronic batteries will be included in the housing.
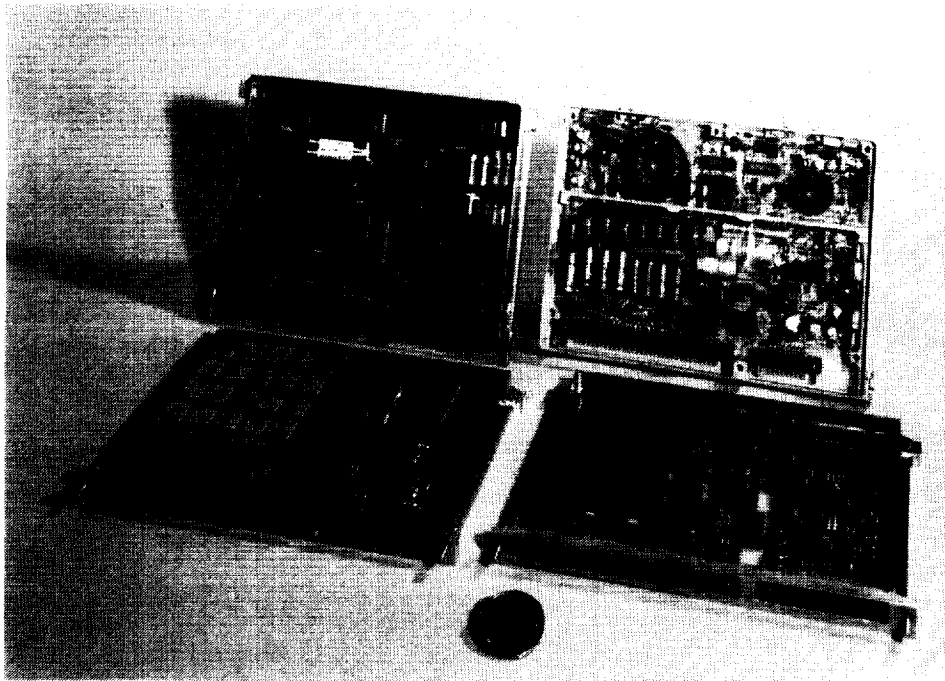
Fig. 3-1: Modules for Experiment Control, Data Management and Storage

Among other features this system allows for higher resolution (12 bit), higher data acquisition rates and easy data evaluation. Due to standard interfaces a PC can be used as EGSE. Data storage will be performed by a semiconductor memory with a basic storage capacity of 10 Mbit. This capacity can easily be expanded in steps of 20 Mbit. Also the number of digital and analog I/D's can be increased or adapted to the needs of a particular experiment. Generally, this new system is much more flexible in use.

4. TWIN-MAUS Configuration

A concept for the extension of MAUS payload resource limits has recently been analysed in the TWIN-MAUS (Two-Interconnected MAUS-Payloads) study. Generally in the existing MAUS system the resources are limited with respect to energy, volume/mass, experiment duration, heat dissipation, and data storage capacity.

The currently developed EURECA experiment HPT (High-Precision-Thermostat) has been chosen as a model payload because it is a rather complex experiment accommodated in a GAS canister with a modified MAUS experiment mounting structure and a modified end plate being used as a radiator. The HPT is an almost autonomous facility providing its own experiment control and data acquisition system. Fluid physics experiments can be carried out within precisely defined temperature ranges.

The resource requirements of the model payload for a typical five day mission have been compared to resources offered by the MAUS system. The energy needed is about 10 kWh and approximately 100 Mbit of data will be generated, both depending on the actual experiment. The facility occupies the whole volume of a standard 5ft. GAS-canister.

To operate an experiment with resource requirements like the HPT, the GAS program offers the possibility of interconnection of GAS-canisters. An appropriate concept has been defined and analysed.

Experiment-MAUS　　　　　　　　　　**Power/Data MAUS**

Data RS422

" Power ON "

Memory

Power

Power

On / Off

Fig. 4-1: TWIN-MAUS Concept

One canister contains just the experiment, in this case the HPT with its own experiment control and data acquisition unit. In the other containner, the needed batteries, a power distribution unit, and a data memory unit are accommodated. All electronics are compatible with or even identical to the new MAUS electronics.
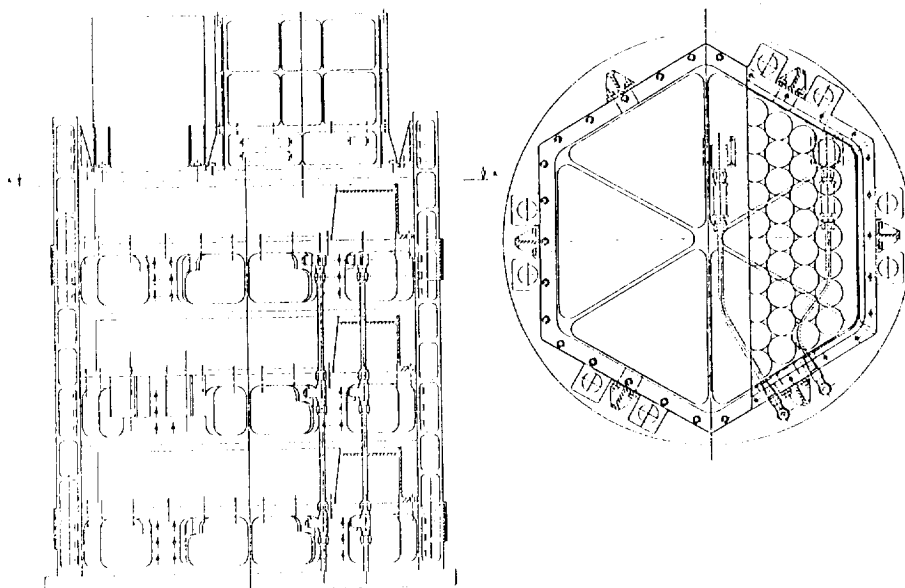
Fig. 4.2 Power/Data MAUS Design

31

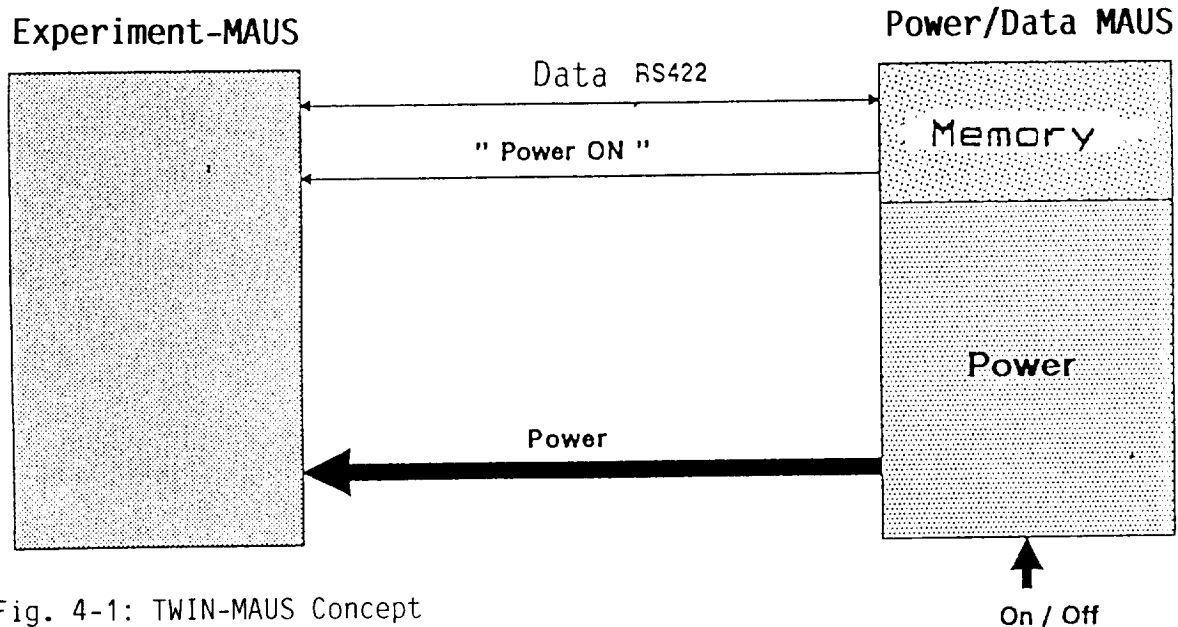The structural design of the Power/Data-MAUS is completely different from the existing MAUS hardware. Due to the limits of mass and load capacity the experiment mounting structure as well as the battery housing can no longer be used. A new self supporting battery housing has been designed. Up to three can be assembled in the Power/Data-MAUS by means of triangular shaped posts. Each of the batteries can be equipped with 180 Li SO_2 cells producing a total energy of 10.5 kWh. The two electronic units are mounted on a platform above the batteries.

A thermal analysis has been performed considering the TWIN-MAUS configu ration. It turned out that all components of the Power/Data-MAUS were within their tempera-ture limits independent of the orbiter thermal attitudes. For the HPT having a power dissipation of 90 W it turned out that a passive thermal control concept is only possible by avoiding hot thermal attitudes. Due to the necessary emission characteristics of the top plate deep space orientations (cold case) have to be limited to 7 hours.

As a rough reference value for other experiments, the thermal analysis showed, that with a maximal power consumption of approximately 75 watts a continuous operation during the whole shuttle mission will be possible. But to get more precise values a detailed thermal analysis is necessary for each particular payload.

As a further aspect of the study the possibility of flying experiments like the HPT in GAS-canisters on the carriers Hitchhiker-G, -M, and DOM (a German payload carrier system), was examined. Only one container will be used in that confi-guration, the resources of the Power/Data-MAUS being provided by the carriers. All carriers offer up- and downlink capabilities, additionally the DOM carrier offers active cooling by a Freon cooling loop. Looking at cost and availability aspects, the TWIN-MAUS configuration offers the most promising possibility to meet the challenge of future advanced payloads.

References:

1. G.H. Otto: Experimental Results from Automated MAUS Payloads. IAF Paper No. 88-351 (1988).

2. S. Staniek, G. Otto and J. Döpkens: Ten Past and Ten Future GAS/MAUS Payloads. NASA CP-2438, pp. 31-38 (1987).

3. D. Baum, G. Otto and P. Vits: MAUS-A Flight Opportunity for Automated Experiments Under Microgravity Conditions. Acta Astronautica, Vol. 11, pp. 239-245 (1984).

Development of Experimental Systems for Material Sciences Under Microgravity

Jun Tanii*, Shinzo Obi*, Yotsuo Kamimiyata* and Akio Ajimine**

Abstract

Three experimental systems --G452, G453, G454-- have been developed for material science studies under microgravity by the NEC Corporation, as part of the Space Experiment Program of the Society of Japanese Aerospace Companies. These systems are to be flown as Get-Away Special payload for studying the feasibility of producing new materials.

The three systems all comprise standard subsystems consisting of : -
- Power supply
- Sequence controller
    - Temperature controller
    - Recorder (data recorder of VCR)
    - Video camera,
together with the experimental modules carrying the hardware specific to the experiment.

1. Introduction

The Get-Away Special (GAS) Program has been offered by NASA to a number of countries including Japan, providing the opportunity to purchase payload space onboard shuttle flights. Japan has already had two experiments flown : -

---

* NEC Corporation Space Development Division, Yokohama, Japan
** The Society of Japanese Aerospace Companies, Inc., Tokyo, Japan

- G-005 for producing artifical snow[1], and
- G-032 for an experiment on the collision between small balls
  of metal and of water[2].

These payloads were developed by NEC under contract with the Asahi Shimbun and the Asahi Broadcasting Company. The Society of Japanese Aerospace Companies and NEC have utilized the experience gained in the development and manufacture of the foregoing two systems to further develop system for studying the feasibility of producing new materials under conditions of microgravity.

The most difficult problems calling for solution in development were to install the maximum possible number experiment modules within the prescribed limitations of space mass, which called for devising a miniaturized furnace for sample melting with minimum power consumption, to reduce the required number of batteries.

2. Overview of Experimental Systems

The principal characteristics and features of the three experimental systems are as summarized in Table 1. The hardware presents the external appearance shown in Figure 1.

The payload support structure is cantilevered out from the Experiment Mounting Plate (EMP), and supported laterally by 4 stoppers arranged on the two sides opposite each other.

As presented schematically in Figure 2, each system consists of an experiment module carrying the hardware specific to the experiment and a standard subsystem --of composition common to all three systems-- comprising 5 electrical circuit units for : -
- Sequence Control (SCU)
- Temperature Control (TCU)
- Power Conditioning
- Alarm
- Interface,
together with auxiliary components convering : -
- Battery assembly
- Transistor power switch unit
- Recording unit.

The SCU controls the ON/OFF status of all the other units

34

|

(Recording, Temperature Control, Experiment Module, ...). While the standard subsystem is thus common in form to all three systems, their substance --mode of control-- varies with the experiments, and to accommodate the variants, a high degree of flexibility has been incorporated in the subsystem, with micro-CPU and its peripherals including ROM --schematized in Figure 3-- adapted to the particular experiments. This flexibility will permit accommodation of alterations in the experimental control scenario by simple replacement of the ROM, even at a fairly late phase of experimental system development.

The Standard Recording Unit stores data from the experiment module (material temperature, heater current and other experimental measurements) as well as from the housekeeping subsystem (ambient temperature, battery voltage, ...). In some runs, in-situ images of crystal growth and other physical phenomena require recording, in which case the data recorder is replaced by a CCD color video camera and video cassette recorder: The monitor signals --e.g. material sample temperature-- are recorded on the audio track of the video tape, and image data on the video track. The video camera presents the external aspect illustrated in Figure 4.

3. Experiment Modules

The 12 experiments listed in Table 2 have been selected by a board of Japanese authorities interested in material science and space technology. Some of the modules have been developed by the experimenters, and others by the present authors.

Representative examples of the experiment modules are shown in Figures 5 to 8. Figure 5 and 6 indicate the arrangement of the miniature furnace or ampoule and material samples devised to satisfy the prescribed limitations of space and mass. These furnaces are embedded in thermal insulator, in the manner shown in Figure 9.

4. Concluding Remarks

The three experimental systems described above have been tested in simulated launch and orbit conditions, and have proved to function as expected. Using these systems, experiments have been successfully conducted for acquiring basic data on ground.

The systems thus developed are destined to be flown on the Space Shuttle in the near future, at which time acquisition can be expected of useful material science data under micro-gravitational condition.

5. Acknowledgments

The authors express their sincere appreciation of the kind cooperation and incessant encouragement accorded to the present study by officials and engineers of the NASA Get Away Special Program. Further acknowledgment is due also to experimenters of The Society of Japanese Aerospace Companies --in Hitachi Ltd., in Fujitsu Corporation, as well in NEC-- for their collaboration. The authors are deeply indebted to the Mechanical Social Systems Foundation under the aegis of the Ministry of International Trade and Industry, for the support accorded to the study as part of the Ministry's plan for promoting the GAS Program in Japan.

[REFERENCES]

Kimura, S et al, 83   :   "Experimental system to Produce
                            Artificial Snow" 83 IAF Congress on the
                            Space Shuttle

Fujimoto, K, 85   :   "WATER BALL COLLISION", 85 GAS
                            Experimenter's Symposium

TABLE 1   MAIN CHARACTERISTICS AND FEATURES
OF EXPERIMENTAL SYSTEMS

	G-452	G-453	G-454
SIZE DIAMETER HEIGHT	50 cm 70 cm	50 cm 70 cm	50 cm 70 cm
WEIGHT	70 kg	80 kg	70 kg
OBSERVATION/ RECORDER	DATA RECORDER	CCD COLOR VIDEO CAMERA VCR	CCD COLOR VIDEO CAMERA VCR
CONTROL	MICRO-CPU.ROM	MICRO-CPU.ROM	MICRO-CPU.ROM
EXPERIMENTS	SEMICONDUCTOR(4)	SEMICONDUCTOR (2) SUPERCONDUCTOR(1) BOILING PHENOMENA (1)	SEMICONDUCTOR (2) SUPERCONDUCTOR(1) FERROMAGNETIC MATERIAL (1)
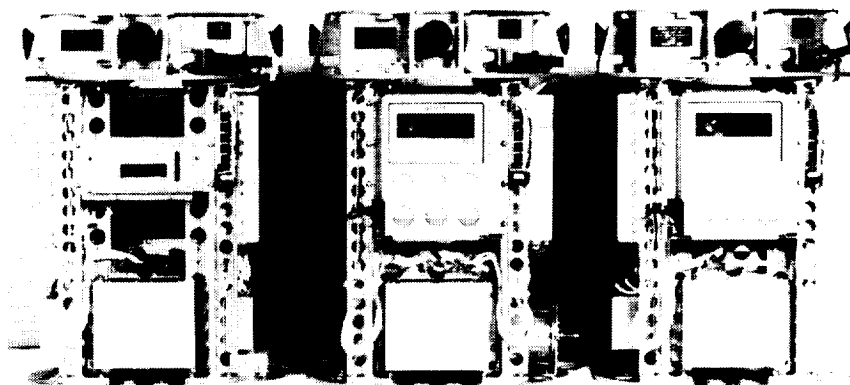
Figure 1   External view   of three Experimental Systems

FIGURE 2

STANDARD BLOCK
DIAGRAM OF
EXPERIMENTAL SYSTEM
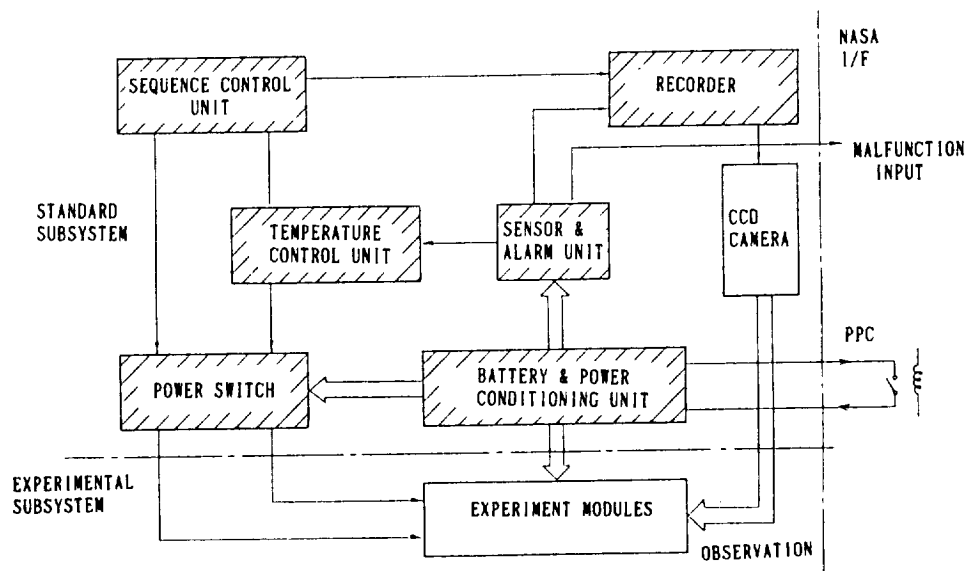
FIGURE 3

SCHEMATIC
DIAGRAM OF CPU
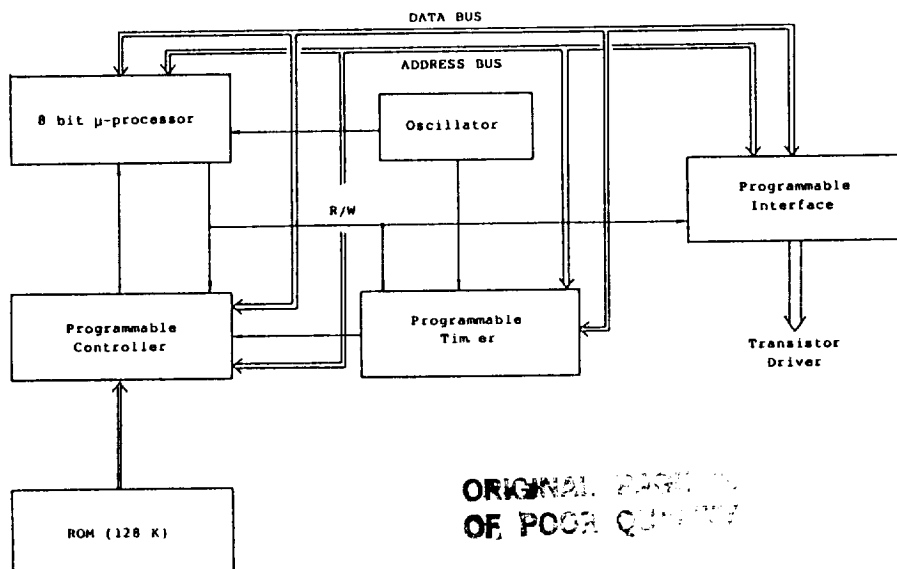
FIGURE 4

**EXTERNAL VIEW
OF CCD CAMERA**
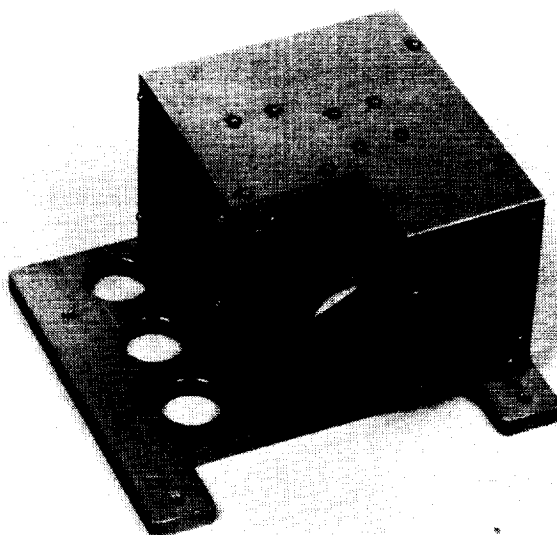
Table 2   Themes of 12 experiments for material sciences

System	No.	Experiment	Theme
G452	1	Semiconductor	Single crystal growth of GaAs from liquid phase (900 c)
	2	Semiconductor	Crystal growth of GaAs based mixed crystal (GaAsSb) (900 c)
	3	Semiconductor	Addition of a heavy element (Bi) to GaAs crystal (900 c)
	4	Semiconductor	Addition of a heavy element (Bi) to InSb crystal (650 c)
G453	6	Semiconductor	Formation of heterogeneous-alloy system from GaAs and Ge (900 c)
	7	semiconductor	Formation of thin-film-type single crystal of compound semiconductor (InSb)
	9	Superconductor	Formation of Si-Pb Alloy (immiscible on the ground) (1450 c)
	12	Boiling	Observation of the bubble form when an organic solvents is boiling under -g. (40 c)
G454	5	Semiconductor	Crystal Growth of In GaAs from vapor phase (800 c)
	8	Superconductor	Crystal growth of NbSe3 from vapor phase (800 c)
	10	Optoelectronic crystal	Crystal growth of an optoelectronic crystal (KH2PO4) by diffusion method (900 c)
	11	Superferromagnetic alloy	Formation of superferromagnetic alloy (Nd-Fe-B) (1400 c)

38

CERAMIC FIBER   CERAMIC COAT   THERMO-COUPLE

QUARTZ AMPOULE

CRUCIBLE   HEATER
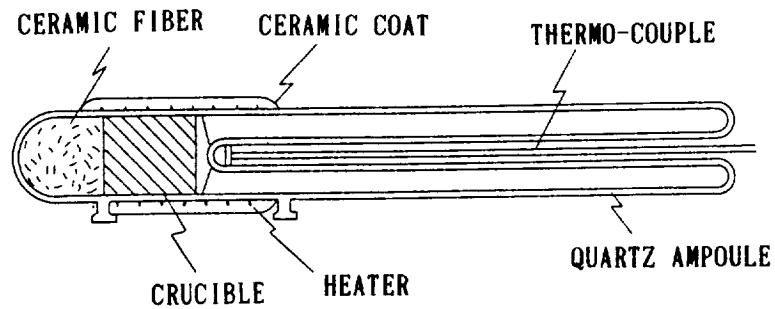
FIGURE 5   SMALL ELECTRIC FURNACES FOR EXPERIMENTS : Nos. 1,2,3.,9,11

QUARTZ AMPOULE   HEATER
(2ND ZONE)

THERMO-COUPLE   CERAMIC COAT   THERMO-COUPLE

POROUS CERAMIC   CRYSTAL SUBSTRATE

HEATER   RAW MATERIALS
(1ST ZONE)

FIGURE 6   SMALL TEMPERATURE GRADIENT FURNACE
FOR EXPERIMENTS : Nos.5 AND 10

FIGURE 7   EXTERNAL VIEW OF EXPERIMENT No. 8 MODULE

39
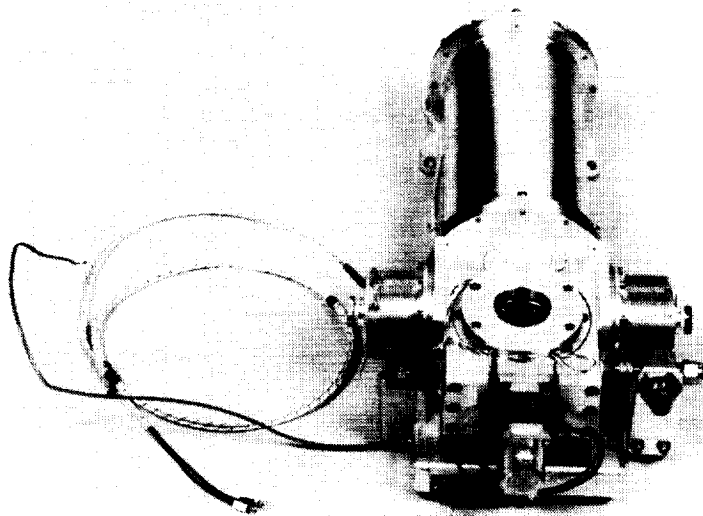
FIGURE 8   EXTERNAL VIEW OF EXPERIMENT No. 12   MODULE

FIGURE 9   SMALL FURNACES EMBEDDED IN THERMAL INSULATOR

HIEN-LO - AN EXPERIMENT FOR CHARGE DETERMINATION OF COSMIC RAYS OF INTERPLANETARY AND SOLAR ORIGIN

B. Klecker, D. Hovestadt
Max-Planck Institute fur Extraterrestrische Physik, 8046 Garching, FRG

G. M. Mason
Dept. of Physics and Astronomy, University of Maryland
College Park, MD 20742, USA

J. B. Blake
The Aerospace Corporation, Redondo Beach, CA, USA

J. Nicholas
Air Force Technical Applications Center, Patrick Air Force Base, FL, USA

Abstract

The experiment is designed to measure the Heavy Ion Environment at Low Altitude (HIEN-LO) in the energy range 0.3 - 100 MeV/nucleon. In order to cover this wide energy range a complement of 3 sensors is used. A large area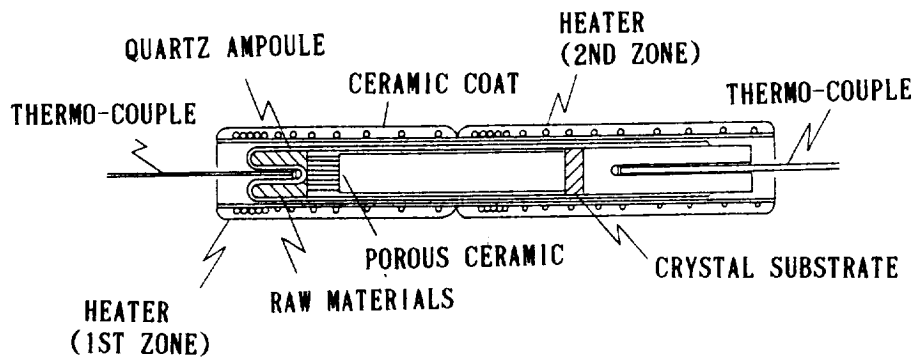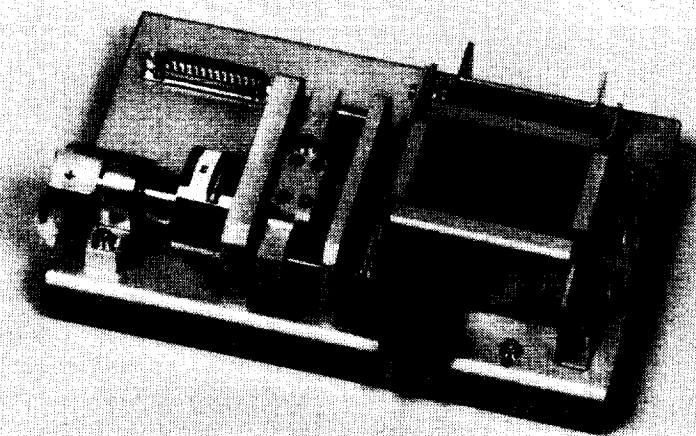 ion drift chamber (Sensor 1) and a time-of-flight telescope (Sensor 2) are used to determine the mass and energy of the incoming cosmic rays (CR). A third omnidirectional counter (Sensor 3) serves as a proton monitor. The analysis of mass, energy, and incoming direction in combination with the directional geomagnetic cut-off allows the determination of the ionic charge of the CR. The ionic charge in this energy range is of particular interest because it provides clues to the origin of these particles and to the plasma conditions at the acceleration site. The experiment is expected to be flown in 1988/1989.

1. Introduction

In 1972 a new component of cosmic rays has been detected [1], [2] with a composition very different from solar or galactic cosmic rays. Because of the peculiar elemental abundances (predominantly helium, oxygen, and neon, no carbon) this component has been called "anomalous cosmic rays" (ACR). A current hypothesis associates the origin of ACR with the interstellar neutral wind. It is assumed that the neutral wind is ionized by solar I/V radiation and charge exchange with protons from the solar wind. After being picked up by the solar wind and the interplanetary magnetic field the ions (predominantly He^+, N^+, O^+, Ne^+) are swept to the outer heliosphere. There the ions (still being singly ionized) are assumed to be accelerated to energies high enough to re-enter into the inner solar system against the effect of solar modulation [3]. The first step of this process has, in fact, been observed recently for He with novel instrumentation onboard the AMPTE/IRM spacecraft [4]. Model calculations, including transport and acceleration are pretty successful in reproducing the observed spectra and abundances of ACR [5], [6]. However, the determination of the ionic charge would give direct evidence for this hypothesis. Ionic charge measurements of solar cosmic rays carry important information on the plasma conditions (temperature, density) at the acceleration site on the sun.

In order to cover a large range in mass and energy the experiment consists of a combination of 3 sensors. A large area ion drift chamber (Sensor 1) and time-of-flight telescope (Sensor 2) are used to determine mass, energy, and direction of the incoming cosmic rays (CR). The energy and mass ranges of sensor 1 and 2 are listed in Table 1. Sensor 1 is optimized for the mass and energy range of the ACR component. Sensor 2 covers the full mass range between helium and iron at low energies. The omnidirectional Sensor 3 serves as a monitor to the proton radiation environment.

2. Ionic Charge Determination

The ionic charge, Q, of an incoming particle can be determined by simultaneously observing the magnetic rigidity $R = 43.3*(A/Q)*(E/A)^{0.5}$ and the energy per nucleon, E/A, where A is the atomic mass number. The instruments are designed to measure the energy, E, of each incoming ion. The mass (or nuclear charge) is determined by the well-known dE/dX versus E method (sensor 1) or by the time-of-flight versus E method (sensor 2). The magnetic field of the earth serves as a rigidity filter which gives access only to particles with rigidities exceeding the local directional geomagnetic cut-off rigidity. This is shown schematically in Figure 1. Only particles with $R > R_{cutoff}$ have access to the experiment. With E, A, and R_{cutoff} an upper limit for the ionic charge Q can readily be computed.

3. Payload Description

The main systems of the experiment are shown schematically in Figure 2. The experiment consists of 3 sensors, the sensor electronics, the central data system (DPU), a tape recorder for data storage and a battery package. The GAS payload will have a motorized door (MDA). Once in space the experiment is activated from the astronaut. This command enables MDA opening and turns on power to the DPU. The DPU then controls all 3 sensors and the data transfer to the tape recorder. At the end of the mission, the payload is returned to its quiescent condition ready for landing by another command of the astronaut. Figure 3 shows part of the experiment package in flight configuration: Sensor 1 (on top), the analog electronics (middle), and the battery box (bottom).

4. Sensor Description

A schematic diagram of Sensor 1 is shown in Figure 4. It consists of a three element ion drift chamber (IC1, IC2, IC3) with a thin entrance window (40μAl) followed by an array of 16 solid state detectors (SSD) and a CsI scintillation counter which is viewed by 4 light sensitive diodes. The first and the third elements of the drift chamber are sensed by two position sensitive proportional counters (PC1, PC2) with back-gammon shaped cathodes. In the first element also the drift time (TOD) of electrons generated along the track of the incoming particle is determined. The drift time is the time elapsed between the response of the SSDs and the anode of PC1. Drift time and position response of PC1 provide two coordinates for the incoming ion at the top of the sensor. At the bottom the position response of PC2 and the information on the detector row triggered by the incoming ion provide another two coordinates. From these 4 coordinates, then, the incident direction of the incoming ions can be derived. The ionization chamber operates with isobutane at a pressure of 75 torr (at 20 C). The density of the isobutane is actively controlled by a gas regulation system providing a continuous flow-through of isobutane. The gas supply consists of 180 g of liquid isobutane

stored in a Tl tank. The geometrical factor of the sensor is 35 cm^2sr.

Figure 5 shows results from a calibration measurement at the Hahn Meitner Institue in Berlin. For this measurement a 800 MeV beam of S^{32} has been scattered on a thick target and the reaction products have been measured with the experiment. The figure shows a matrix of the ionization chamber versus energy signal and demonstrates the high mass resolution and low background of the system. In orbit the multi dE/dX - E measurement (PC1, IC2, PC2, SSD and/or CsI) will provide even better mass resolution and background rejection.

Sensor 2 (LAT) serves to identify and analyze the particles below 6 MeV/nucleon from H to Fe. The particles are identified by measuring the time, TOF, required to travel between a thin aperture foil and an array of solid state detectors. The timing signals are obtained from secondary electrons emitted when the particles penetrate the foil and the front surface of the solid state detectors: these electrons are accelerated and deflected onto microchannel plates which produce fast pulses suitable for START and STOP signals for a timing measurement. The solid state detector measures the kinetic energy $E = 1/2 \, mv^2$ after taking account of the energy loss in the entrance foil and in the detector by nuclear defect. Since the flight path length between the foils and the detectors, λ, is known, the TOF and E measurements may be combined to yield the particle mass via $A = 2*E*(TOF/\lambda)^2$. In the configuration shown in Figure 6 the time-of-flight sensor has a flight path length, λ, of 50 cm, and a geometrical factor of 1 cm^2sr. For a threshold of 0.3 MeV/nucleon for heavy ions, such a geometrical factor is large enough to analyze contributions from solar flare particles to the fluxes observed by sensor 1 above 6 MeV/nucleon. If a solar energetic particle event occurs during the mission, it would be possible to resolve isotopes of all elements from Helium through Silicon (and would resolve elements and some isotopes beyond Silicon). Figure 7 shows the He^4 track in a TOF - E matrix obtained from the prototype Sensor 2. The particles are from an alpha source. The alpha particles in the test pass through a variety of foil thickness to yield a range of incident energies centered around 0.6 MeV/nucleon. Notice the excellent mass resolution (σ_m = 0.06 amu) and low background in the matrix.

5. Acknowledgement

We acknowledge the effort of many individuals at the Aerospace Corporation, the Air Force Technical Applications Center, the University of Maryland, and the Max-Planck Institue fur Extraterrestrische Physik who contributed to the design, manufacturing, and testing of the instrumentation.

References

1. M. Garcia-Munoz, G.M. Mason, J.A. Simpson, 1973, Ap. J. (Lett.) 182, L81.
2. D. Hovestadt, O. Vollmer, G. Gloeckler, and C.Y. Fan, 1973, Phys. Rev. 31, 650.
3. L.A. Fisk, B. Kozlowsky, and R. Ramaty, 1974, Ap. J. (Lett) 190, L35.
4. E. Möbius, D. Hovestadt, B. Klecker, M. Scholer, G. Gloeckler, and F.M. Ipavich, 1985, Nature 318, 426.
5. B. Kecker, 1977, J. Geophys. Res. 82, 5287.
6. J.R. Jokipii, 1986, J. Geophys. Res. 91, 2929.

Table 1: $\sigma_m < 0.6$ AMU
(ADJACENT ELEMENTS RESOLVED)

| Species | Energy Range (MeV/nucleon) | |
	Sensor I	Sensor II
^{4}He	3.5 - 95	0.30 - 6.1
^{12}C	6.0 - 150	0.36 - 8.9
^{16}O	6.8 - 120	0.40 - 6.6
^{20}Ne	7 - 100	0.41 - 5.6
^{24}Mg	7 - 100*	0.58 - 4.5
^{28}Si	*	0.43 - 3.85
^{32}S	*	0.46 - 3.10
^{56}Fe	*	0.56 - 1.26

*Separation possible only for every other element
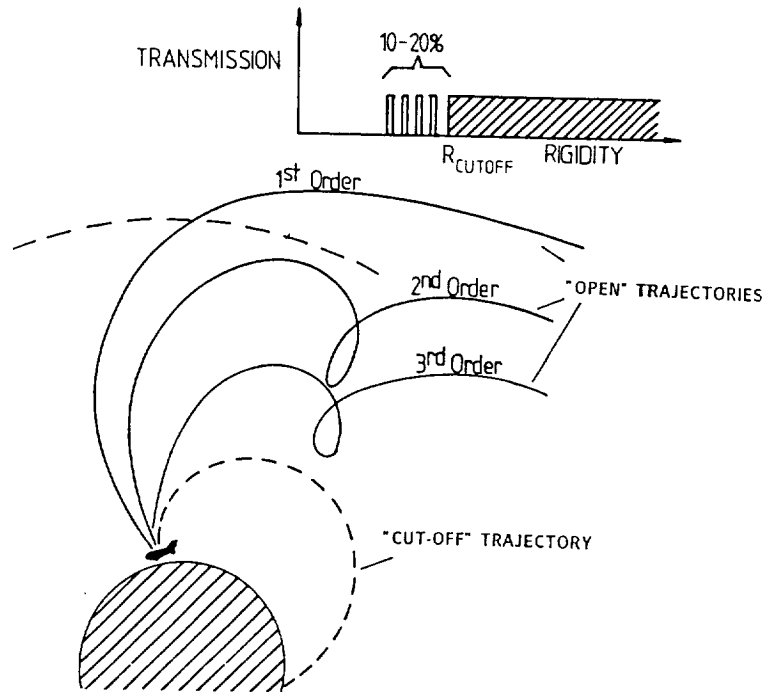
Fig. 1: Schematic picture of cosmic ray trajectories impinging from different directions with respect to the experiment axis.

TOP VIEW

0   10   20 cm

FOV=94°   FOV=22°

LID (OPEN)

dE/dx
CHAMBER

SENSOR I

EXP. ELECTRONIC

TIME
OF
FLIGHT
SENSOR
II

CENTRAL
DATA
SYSTEM

TAPE
RECORDER

BATTERIES

NASA
INTERFACE AREA

SENSOR
I

SENSOR
II

SENSOR
III
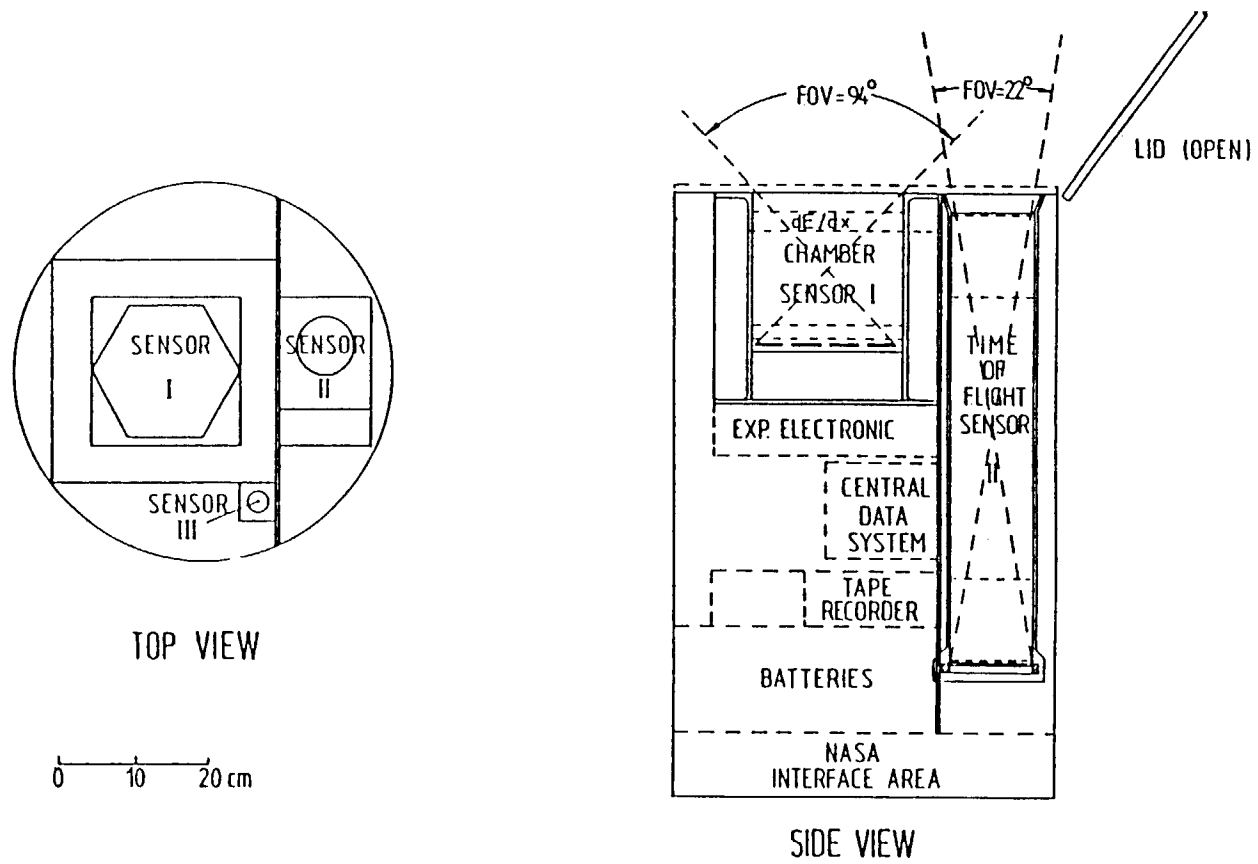
SIDE VIEW

Fig. 2:   Top and side view of the experiment package (schematic).
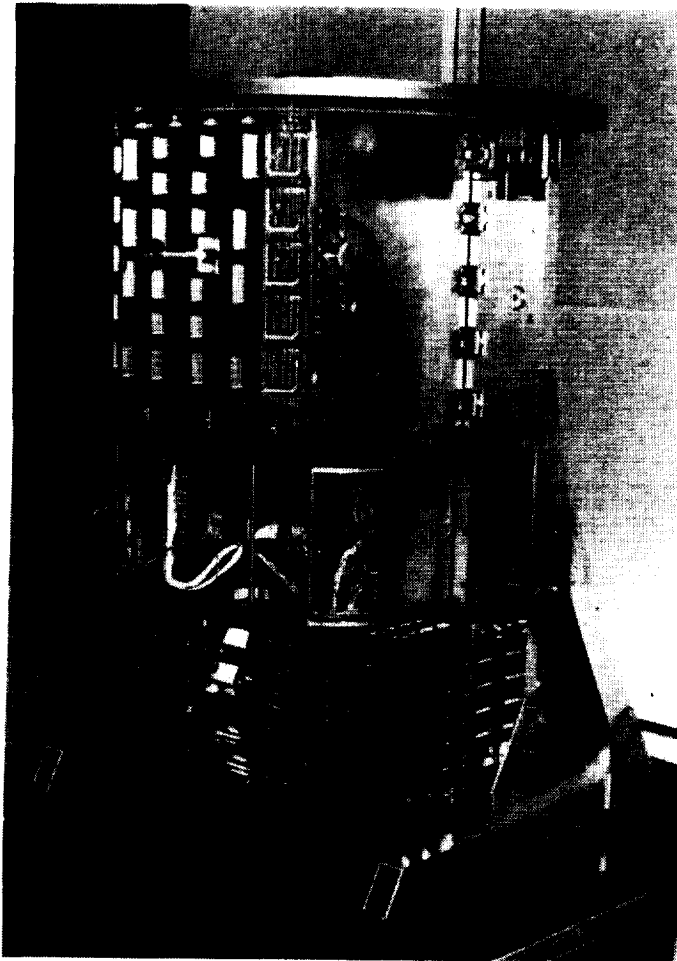
Fig 3. Sensor 1 (top), electronic box
(without DPU, module), and battery box
(bottom) in flight configuration.

46
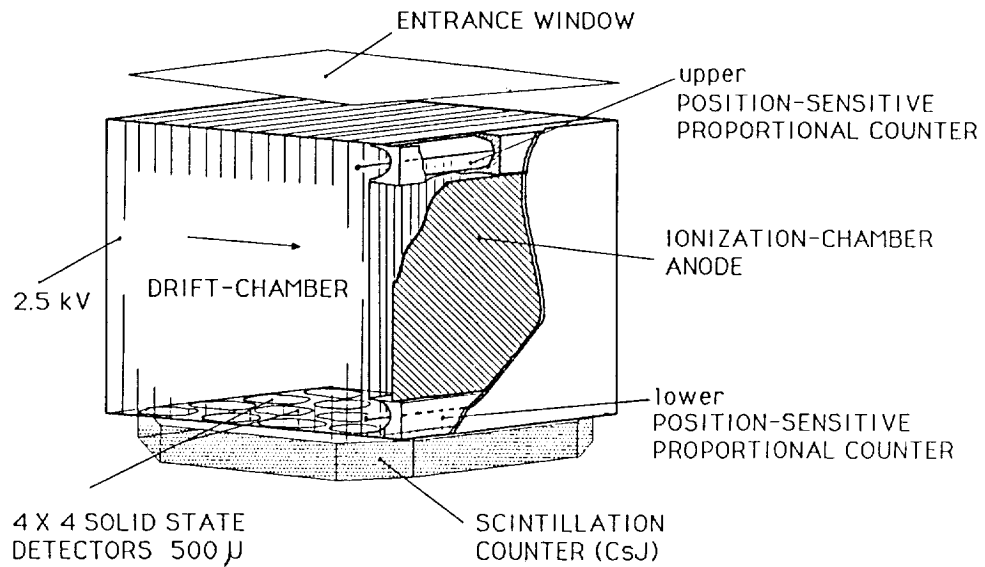
Fig. 4: Schematic view of sensor 1. The drift chamber size
is 19 x 19 x 18 cm.
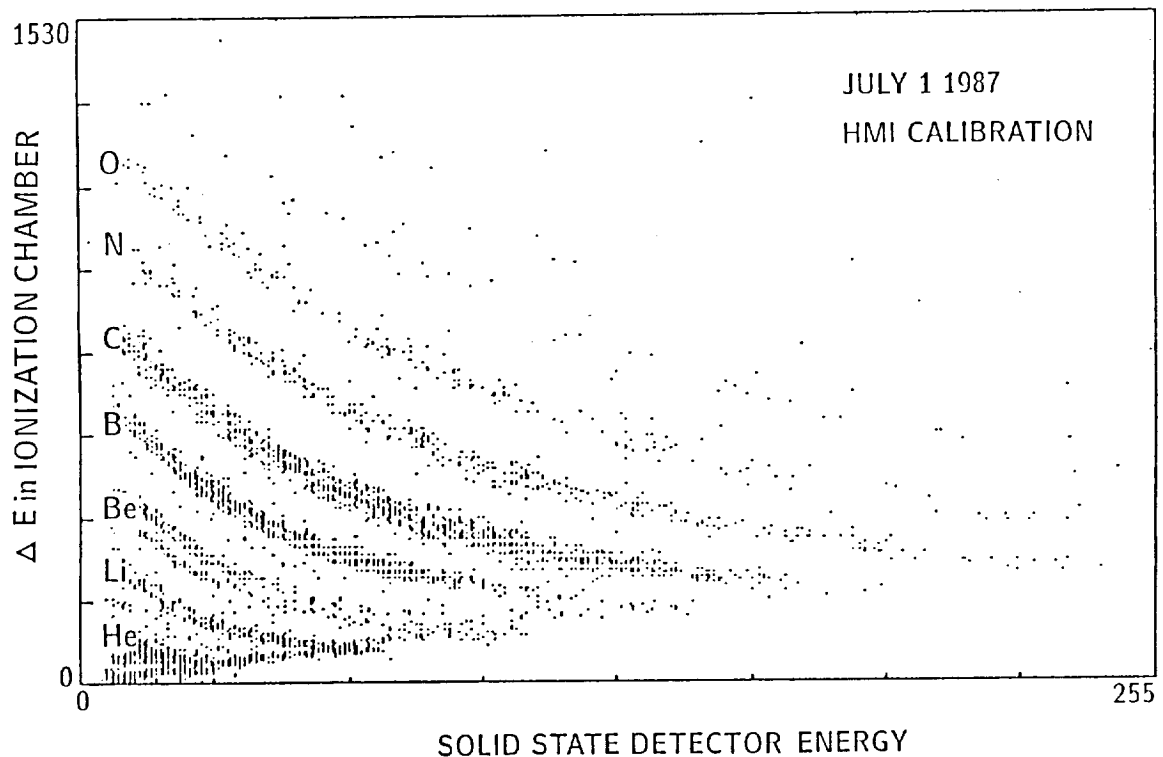
Fig. 5: Ionization chamber versus energy left in the solid state
detector. Data are obtained with the flight unit at the HMI
cyclotron in Berlin.

Get Away Special (G-0335)

Telescope

thin foil
Harp at ~1kV
Electrostatic mirror

"Start" MCP

e$^-$

Secondary electron path

typical ion path

"Stop" MCP

e$^-$

Electrostatic mirror

Harp at ~1kV

Solid State Detector Array

Scale
5 cm
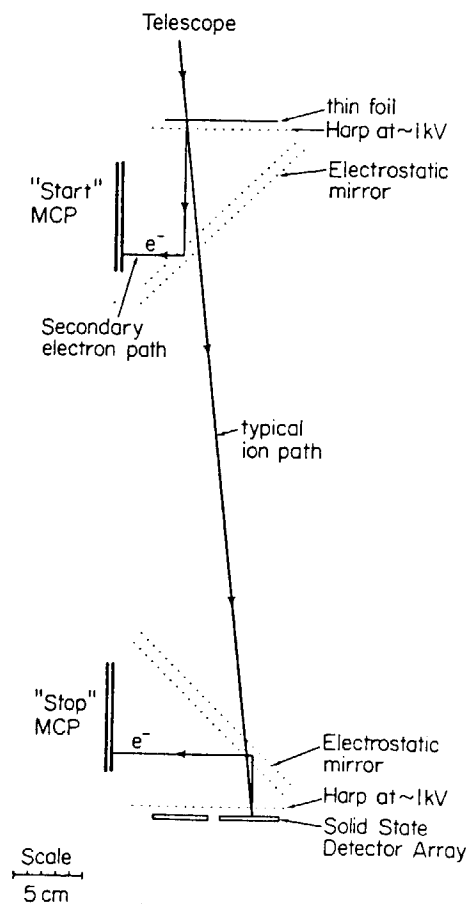
Fig. 6: Cross section of active elements of sensor 2.
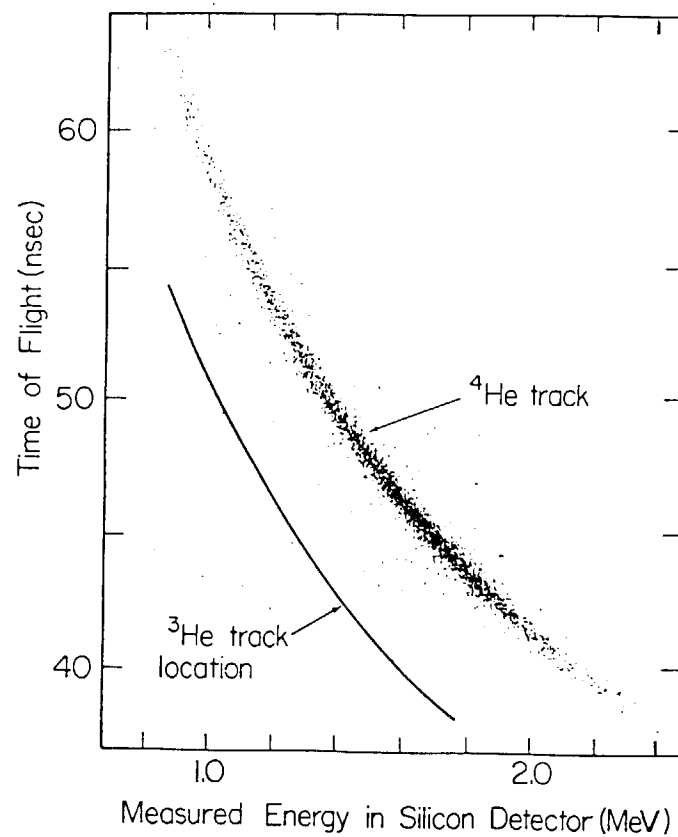
Fig. 7: Time-of-flight versus energy left in the SSD. Data are obtained with the prototype instrument using an alpha source.

CSCP

A NEW GET AWAY SPECIAL (GAS) PROJECT

Jack J. Gottlieb
GAS Senior NASA Technical Manager

Goddard Space Flight Center
Greenbelt, MD 20771

ABSTRACT

The Get Away Special (GAS) Program has instituted a new project called Complex Self Contained Payloads (CSCP) designed to support GAS type payloads that are beyond the scope of the GAS program. These payloads may be supported by GAS personnel and hardware and will fly as primary or secondary Shuttle payloads using the standard NASA Form 1628.

INTRODUCTION

The National Aeronautics and Space Administration's (NASA) Space Transportation System (STS) is built around a reusable vehicle called the Space Shuttle and is designed to provide routine access to space for a wide variety of payloads and users.

The Small Self Contained Payloads (SSCP) Get Away Special (GAS) Program was developed to provide certain types of payloads with a low cost way into space.

A review of the requirements of some GAS users has revealed that the very complex, classified or potentially hazardous payloads do not fit within the scope of the SSCP/GAS program. Further investigation exposed a definite need for a project that would support these payloads economically. It was then determined that GAS hardware and GAS personnel expertise would be an invaluable asset toward supporting these payloads.

The above considerations led to the decision to implement a new project within the scope of SSCP but apart from the GAS Program. This new project is called Complex Self Contained Payloads (CSCP).

PURPOSE

The purpose of the CSCP Project is to provide a flight carrier system and technical support to the user community whose small self contained payloads are complex, classified or potentially hazardous. The nature of these payloads precludes their inclusion in the GAS program. All CSCP payloads would be manifested according to the current NASA primary or secondary payload policies.

SSCP CLASSIFICATION

A. <u>GAS</u> – Candidate payload requirements for the standard GAS payload (Reference: NASA 14CFR Part 1214, Space Transportation System: Use of Small Self Contained Payloads) include:

1. The payload mission requirements are not Shuttle mission drivers.

2. The payload utilizes the normal GAS accommodations including optional services such as opening lid and ejection system.

3. The payload has no residual hazards.

4. The payload is not classified.

5. The payload can fly within the normal GAS queuing system.

B. <u>CSCP</u> – A payload may be a candidate for CSCP if it cannot fly in the GAS program for any of the following reasons:

1. The payload mission requirements may be Shuttle mission drivers.

2. The payload requires more than normal GAS accommodations but is still self contained.

3. The payload has residual hazards.

4. The payload is classified.

5. The payload cannot fly within the normal GAS queuing system.

CSCP Determination

GAS payloads and potential GAS payloads that are reviewed and are
determined to be beyond the scope of the GAS program may be
recommended for inclusion in the CSCP Project. A payload may also
be considered as a candidate for CSCP on the request of the Payload
Organization.

CSCP Requirements

Payloads that are identified for the CSCP project will have a
Form 1628 (old Form 100) submitted to STS for approval. All payloads
in the CSCP project may have use of GAS technical coordination, GAS
carrier elements, GAS integration and preparation support as agreed
upon by NASA Headquarters and the Goddard Space Flight Center.
Specifics of the support will be detailed in a Support Requirement
Plan (SRP) - an agreement between the customer and the CSCP. STS
mission unique costs will be the responsibility of the payload
organization. Each CSCP payload must maintain its self-contained
concept and not require any services from the Shuttle other than mission
timeline and safety considerations.

Each payload in the CSCP will require a separate STS Payload Integration
Plan (PIP) and associated Annexes as well as a full phased safety review
process. It is estimated that the CSCP Project will support two to four
payloads each year based on the support requested.

CSCP Costs

The costs of the standard and mission unique support for each of the
CSCP will be done on a case-by-case basis.

CSCP Participation

The CSCP Project proposes to provide the Basic Support Package (BSP)
at a fixed cost. The BSP consists of:

    a. Technical coordination and equipment compatibility reviews.

    b. Payload carrier system.

    c. Integration support at the Kennedy Space Center (KSC).

The CSCP Project may offer additional support on a limited basis, but not limited to, the following areas:

a. System safety support

b. Flight operations support

c. Unique flight and ground hardware

d. STS integration documentation

All requests for additional support must be agreed to by CSCP management and included in the SRP.

STS Safety Approval Process
for Small Self-Contained Payloads

by

Mary A. Gum
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

Abstract

The purpose of this paper is to present to current
and future users a description of the safety approval
process established by the National Aeronautics and Space
Administration (NASA) for Get Away Special (GAS)
payloads. Although the designing organization is
ultimately responsible for the safe operation of its
payload, the Get Away Special team at Goddard Space Flight
Center will act as advisors while iterative safety
analyses are performed and the Safety Data Package inputs
are submitted. This four phase communications process
will ultimately give NASA confidence that the GAS payload
is safe, and successful completion of the Phase III
package and review will clear the way for flight aboard
the Space Transportation System (STS) orbiter.

Introduction

All Get Away Special (GAS) payloads and canister
hardware which are to be considered for space flight on
the Space Transportation System (STS) must meet certain
design criteria prior to flight and ground safety
approval. The Goddard Space Flight Center (GSFC) Special
Payloads Division is responsible for ensuring that each
GAS payload assembly and its associated ground support
equipment (GSE) is safe and complies with the requirements
of NHB 1700.7, Safety Policy and Requirements for Payloads
Using the STS, and STS Payload Ground Safety Handbook, KHB
1700.7.

Safety approval is typically divided into four steps,
designated as Phases 0, I, II and III, which are
reiterated as payload design is defined and gradually
finalized, and as potential hazards associated with that
design are identified. For most standard GAS payloads,
the STS Safety Review Boards at the Johnson Space Center
(JSC) and the Kennedy Space Center (KSC) become involved
in the safety approval process only at the Phase III level
of review; Goddard Space Flight Center is responsible for
the intermediate 0,I and II levels of payload approval.

The results of each GSFC internal review and all hazard verification controls are incorporated into a final document, the Phase III Safety Data Package (SDP), and a Phase III safety review is conducted jointly with the Johnson Space Center for flight operations, and with the Kennedy Space Center for ground operations. For approval of more complicated payloads, JSC and KSC may participate much earlier in the process and would approve the payload at each level of review.

Payload Accomodations Requirements

The Payload Organization (PO) submits the first safety data as part of the Payload Accomodations Requirements (PAR) document. This occurs approximately twelve to fourteen months before launch, and corresponds to a Phase 0 level review. The purpose of the PAR is to identify major payload subsystems and to assess the applicability of a payload within the GAS program requirements and limitations.

Included in the PAR are a description of the payload hardware conceptual design, proposed operational requirements, and any safety related conditions or possible areas of concern. It is not important that all pertinent information be available at Phase 0, simply that a cursory look has been given and will be updated as other safety concerns become apparent throughout the process. This information is reviewed by GAS flight and ground operations personnel, GAS and JSC safety engineers, and the NASA Technical Manager (NTM), who is the single point of contact between GSFC and the PO. All comments from these participants are incorporated and finalized as a baseline PAR.

Phase I (Preliminary Design)

The Phase I iteration of the safety review process, submitted as a Preliminary Safety Data Package, provides more information on the safety critical components and operations of the GAS payload. A more detailed device description, hardware sketches and other preliminary illustrations should be included as part of this document. Potential payload-related hazards and proposed safey controls and inhibits should be discussed, and a hazard control verification plan developed for evaluation. Hazard reports for each identified hazard should also be submitted with the Preliminary Safety Data Package.

Hazards are categorized as either critical or catastrophic. A critical hazard is defined as anything that could cause unintentional damage to the orbiter, proximity payloads or the GAS container itself. Critical hazards must be controlled to one failure tolerance, meaning the payload must remain safe even after one credible component failure. Those hazards which could result in personnel injury, loss of the orbiter, or destruction of STS and other equipment are considered catastrophic, and must be shown to be two failure tolerant. The data provided by the PO must substantiate the above when addressing each potential hazard.

The Preliminary Safety Data Package is distributed to members of the GAS team for independent review. A joint review is then held with the NASA Technical Manager and GAS safety and operations personnel to discuss questions or areas of concern regarding the information provided. Pertinent GSFC technical experts are also available for consultation if necessary. The Payload Safety Officer (PLSO) incorporates all comments from this review into one marked-up version of the safety package, which is sent to the Payload Manager along with a letter of clarification of those comments.

Several weeks after the SDP is returned to the Payload Organization, a telephone conference is scheduled by the NTM and Payload Manager to discuss any questions the PO may have concerning the GSFC Phase I review. This discussion is typically focused on the incorporation of additional information in preparation of the Final Safety Data Package required for Phase II of the review process.

Phase II (Final Design)

At Phase II, fairly detailed hardware illustrations, system or subsystem block diagrams, and detailed schematics showing the necessary hazard controls are required. As payload design proceeds, more detail is needed on hazards that could affect STS flight and ground operations and crew. Payload descriptions must begin to include specific information about payload subsystems, potential hazards and proposed controls, and methods of verifying hazard controls.

During this period, the payload organization must begin to submit a reviewable summary of each hazard verification method. This information would include, for

example, structural and other analyses, a parts and materials list of all payload components, and results of such things as vibration testing, leak and proof pressure testing of sealed containers, and functional testing of fuses, temperature and low voltage cutoffs, and other battery or circuitry malfunction controls. These summaries are reviewed, independent of the payload organization, to ensure that the data contained therein is complete and accurate, and successfully meets the requirements for controlling hazardous functions or subsystems. Copies are kept on file with GAS safety engineers for future reference if necessary.

As before, GAS safety engineers independently review the system inputs, recommend changes or additions to the identified hazards, and review and approve the safety verification of these hazards. The PLSO incorporates this data into a marked-up copy of the Final Safety Data Package which is again sent to the Payload Manager via the NTM. Another telephone conference is scheduled to clarify any questions about the Phase II review and discuss additional information needed to prepare the Phase III Safety Data Package, including completed hazard reports, for submittal to the JSC and KSC Safety Review Boards.

GSFC Phase III

The Phase III Safety Data Package is the final submittal of safety information. It states that adequate analysis and testing of the GAS payload has been performed and identifies all hazards that could be associated with the operation or malfunction of the payload or payload component. The Phase III package must include a detailed discussion of appropriate safety measures which have been implemented to effectively eliminate or control these hazards.

Each hazard report is considered a stand-alone document at the Phase III level. All credible failure modes of a payload must be identified by this point, and the hazard potential of each specific failure must be assessed. Hazard controls and methods of verifying that those controls are in place and operational are established to ensure that all unsafe conditions are inhibited to an acceptable level of safety risk, i.e. one or two failure tolerant. Verification methods may include tests, analyses or inspection, and similarity to other payload designs may sometimes be used if approved by the GAS and STS Safety Review Boards.

The status of each verification method must be tracked as payload design proceeds. An item is considered to be "open" until a test or analysis is complete and the results have been submitted and approved by GSFC. In general, all verification methods must have a "closed" status before Phase III safety approval will be given. Along with a "closed" status, supportive data for each method of hazard control verification must be included for future reference or auditing. This data would include, but is not limited to, test and analysis report numbers, inspection procedure numbers, quality control log book references, drawing numbers and completion dates.

In some cases, the Phase III Safety Data Package may be submitted to the STS with "open" status items. For example, procedures which are to be performed as part of final payload preparation at KSC would remain "open" until payload close-out. However, a copy of the procedure must be on file with GAS personnel, and reference to the specific procedure number as part of the hazard report is required.

STS Phase III

Upon GSFC Phase III approval, the Phase III Safety Data Package is submitted by the GAS project to both the KSC and JSC for review. Included with this submittal are a signed Certificate of STS Payload Safety Compliance signed by the GAS Project Manager, and a letter of approval from the GSFC Materials Control and Applications Branch for all parts and materials used on the payload.

KSC reviews are focused on potentially hazardous ground payload processing operations such as battery top-off charging and hoisting, and the use of other ground support equipment and tools brought to KSC by the payload organization. The JSC safety board reviews payload flight operations for compatibility with manned-flight requirements and regulations, and ultimately determines that a payload is safe for flight aboard the STS orbiter.

These reviews are typically handled administratively between NASA centers, however in some cases a formal review may be required. If so, the appropriate GAS safety personnel would meet with STS safety personnel to clarify any outstanding issues and generate an acceptable, approved Phase III Safety Data Package.

As part of updated post-Challenger documentation requirements, those GAS payloads which had previously been approved through STS Phase III prior to January 1988 are now required to submit a Delta Phase III Safety Data Package. The purpose of this additional step in the aproval process is to ensure the STS safety boards that the payload has been reevaluated and remains in compliance with NASA safety standards and regulations. Prior to STS resubmittal, new signatures of approval are required from the GAS Project Manager, GAS Safety Engineer and the GSFC Materials Control and Applications Branch for reexamined parts and materials usage.

Post Approval

Receipt of STS flight and ground safety approval is the final step in the review process. The GAS payload is then appropriately inserted into the GAS manifesting queue to await a flight opportunity. Once manifested, the Payload Organization delivers the payload to KSC, where final preflight inspection is performed by the GSFC. In some cases, a verification or demonstration of the hazard controls referenced in the safety documentation may be requested. This inspection verifies that the payload is exactly as described in the safety information previously provided, and is indeed safe for STS flight.

Conclusion

The four phase safety review and verification process established for small, self-contained payloads, and specifically Get Away Special payloads, is an important process which ultimately gives NASA confidence that a GAS payload assembly is safe and is in compliance with STS safety regulations as defined in NHB 1700.7 and KHB 1700.7. The requirements set forth by NASA in those documents are intended to protect flight and ground personnel, the STS, other payloads and associated ground support equipment and the environment from payload-related hazards.

The information provided in the Safety Data Packages should become more specific and complete with each successive step in the approval process. For each phase of review, the Get Away Special team at Goddard Space Flight Center will act as advisors while iterative safety analyses are performed and these Safety Data Package inputs are submitted. Several iterations help to ensure that all potential hazards associated with a GAS payload have either been eliminated by design, or are controlled to an acceptable level of risk.

By establishing regular safety communications early in the system development, the payload organization will benefit from GSFC and STS safety engineering experience, and therefore possibly avoid costly or time consuming design errors; cooperation throughout this communications effort will result in a GAS payload design which is considered safe and flight ready. Upon successful completion of the Phase III Safety Data Package and review, the GAS payload will be appropriately inserted into the GAS manifesting queue, and will ultimately be awarded a flight opportunity aboard the STS orbiter.

References

1) NHB 1700.7 "Safety Policy and Requirements for Payloads Using the Space Transportation System"

2) KHB 1700.7 "STS Payload Ground Safety Handbook"

3) JSC 13830 "Implementation Procedure for STS Payloads System Safety Requirements"

4) "Get Away Special Payloads Safety Manual", May 1986

SYSTEMS REPORT FOR PAYLOAD G-652:   PROJECT ORIGINS

J. Bellina, M.D., Ph.D., M.C. Muckerheide, J. Clark, M. Petry, D. Seeley, R. Sportiello, R. Sprecher, M. Theiler

This paper reports on experiments conducted during the past year which investigated possible hardware configurations and methodologies for our payload project.

Test Data collected from the operation of a free electron laser wiggler using simulated ram glow phenomenon are described.

Results of an experiment to synthesize organic compounds within a primordial atmosphere using a laser induced plasma are discussed.

An experiment is described which utilized neutron bombardment to assess the risk of genetic alterations in embryos in space.

Because of limited space for the amino acid experiments, we have configured the device with a major effort toward miniaturization. The original single chamber concept has been eliminated to prevent a large array of chemical and gas storage along with robotic measuring devices which could encumber the experiment. Collection of the amino acids from a single chamber also is difficult. Therefore, various gas and chemical mixes will be housed in small 2cc vials which will be irradiated by laser to produce a small plasma within them. This configuration allows us to have the samples already collected and isolated after the plasma (spark) has caused the combination to occur.

The failure of mixing because of valve or relay latch up from a dispenser array is eliminated and discrete amounts of the elements can be stored in minor amounts thus eliminating the hazards associated with large volumes of gases.

The laser initiated plasma (spark) is easily positioned within the 2cc vial as is shown in Fig. I.
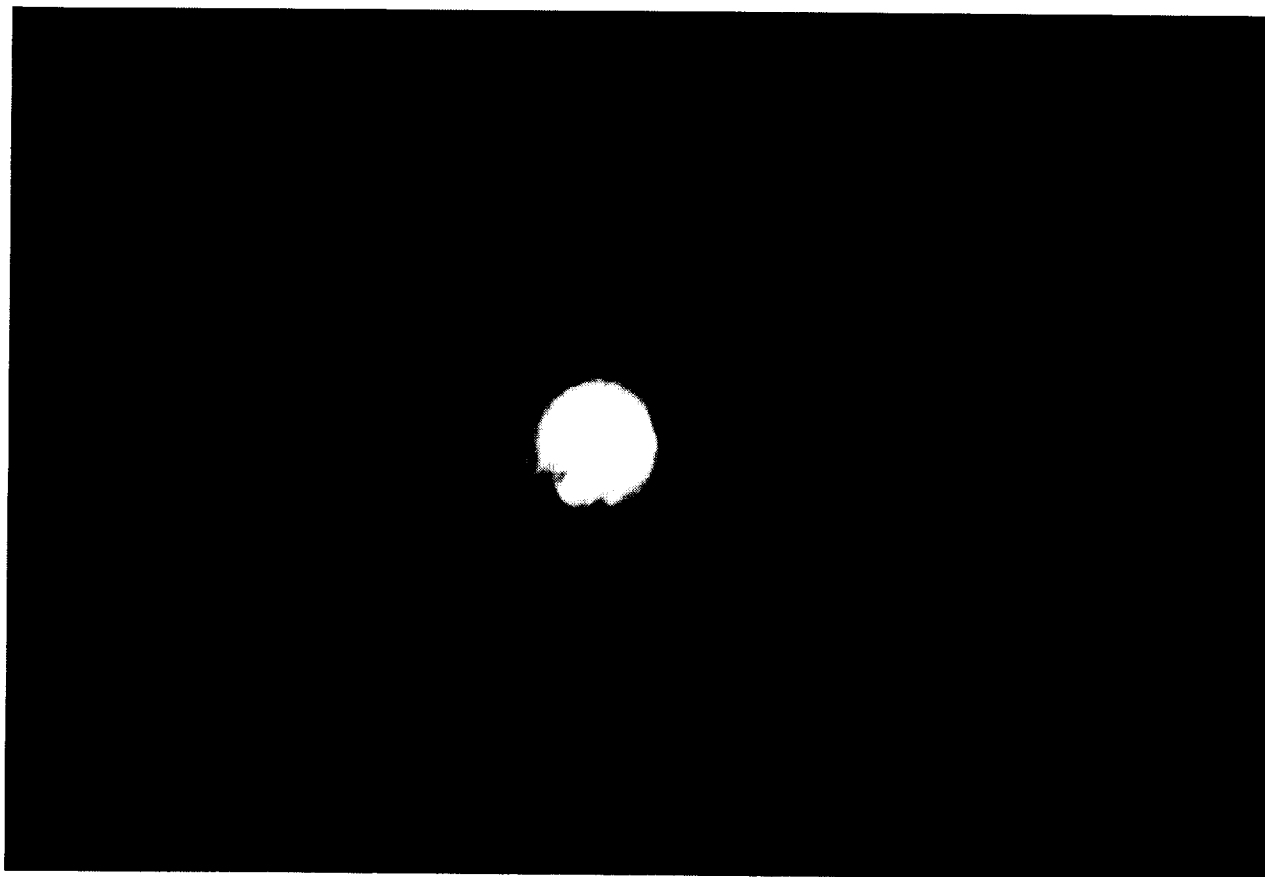
Fig. I
2cc vial with laser initiated plasma within the vial and gases with an electrode free environment.

The original experiment in the 1950's produced amino acids by introducing an electrical spark into a chemical environment which replicated the primordial atmosphere. The problem as we see it with such a device is that the electrodes themselves boil off, or sputter metallic material into the environment. The use of a laser spark (plasma) within a vial containing a chemical atmosphere eliminates the electrode variable in the experiment and allows us to look closely at the combined materials minus the electrode contaminants. Care must be taken to prevent the laser induced plasma from contacting the vial wall as is seen in Fig. II. Contamination of chemical atmosphere could result from contact of the plasma with the vial wall.

62
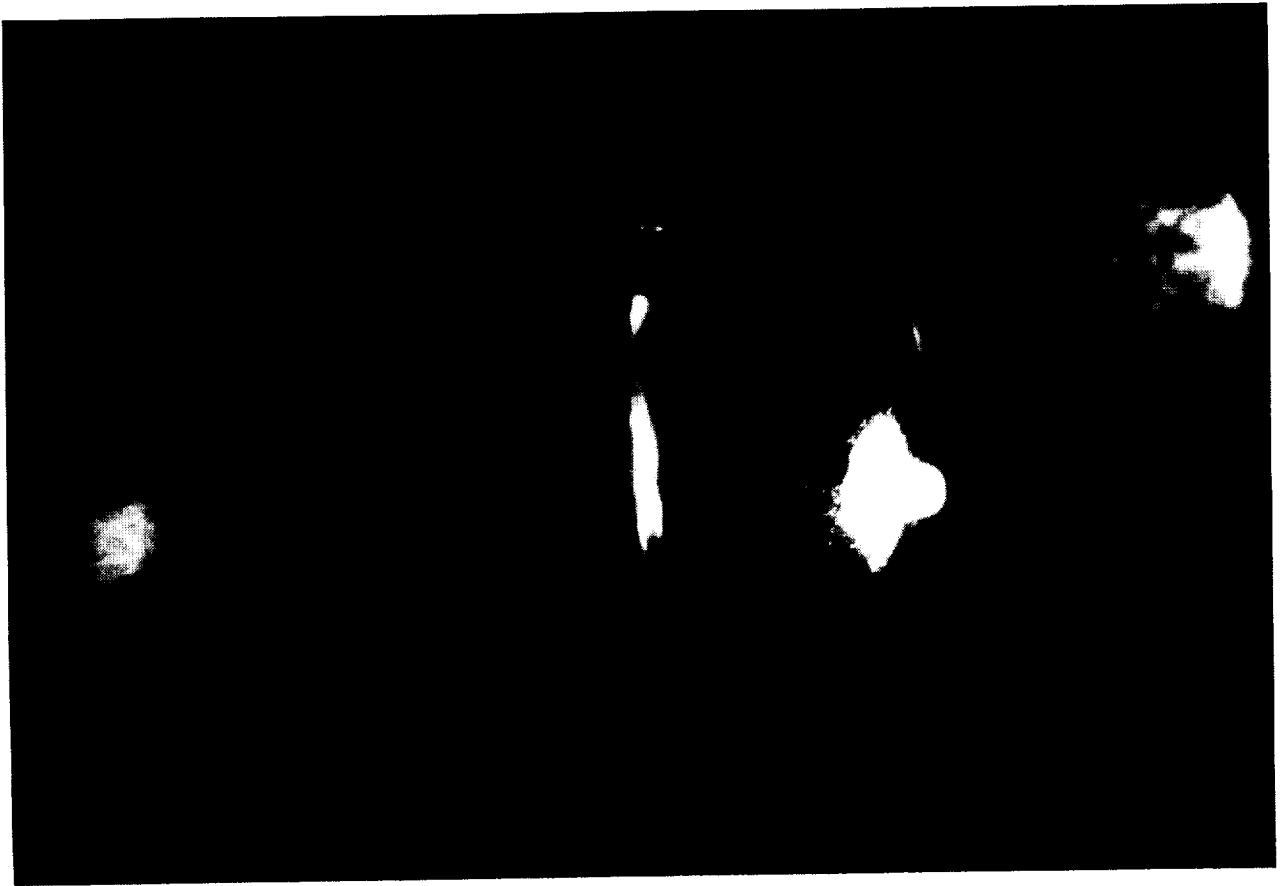
Fig. II
Improper focusing of laser light results in plasma production too close to
vial wall.

The free electron laser wiggler configuration was introduced into a vacuum
chamber and the remaining gases excited with high voltage. The magnetic lines
of force were evident as they related to the magnetic array.

In near earth orbit, our GAS payload will be subjected to a cosmic ray
flux of nearly 2000 impacts per square meter per second. These cosmic rays
are known to consist primarily of protons and alpha particles, travelling at
very nearly the speed of light. It is virtually impossible to simulate this
environment on the surface of the earth. In an attempt to assess the effects
of cosmic ray bombardment on a biological sample, we have placed biological
samples in a neutron howitzer.

The neutron howitzer used contains a 5 curie plutonium source, mixed interstitially with beryllium. This results in the release of about ten million fast neutrons per second, which are moderated by a water jacket, and also gamma rays. The biological sample was placed in proximity to the neutron source, so that it was irradiated by thermal neutrons and by gamma rays, as a simulation of the actual cosmic ray bombardment that will be encountered in orbit.

Neutron and gamma ray bombardment of biological samples in order to assess the risk of genetic alterations in space due to cosmic rays has limitations. In our case, the result of placing the biological sample in the howitzer was the death of the sample in a manner of minutes. As a form of ionizing radiation of very high particle energies, cosmic rays should pose a risk of genetic alterations in biological samples. This thesis will be tested in earth orbit.

For the actual experiment, we have chosen to place the embryos in several cylindrical vials, surrounded by a detector stack consisting of CR-39 and Lexan. In this way we hope not only to gain information regarding the number of hits suffered by our sample, but also the trajectory of the cosmic ray particles. Subsequent microscopy and/or electron microscopy could further aid in determining the effects of cosmic rays on the genetic structure of the samples.

GAS-611
FIREFLY IN ZERO GRAVITY
PROJECT MGR: TONY WILLIAMS

DELTA-t
526 Hemlock Ln.
Lebanon, Pa. 17042

ABSTRACT:
    A study of Insects in a Micro-Gravity environment has not
been investigated to date. There have been some short duration
experiments on animals and plants. Long duration ZERO-G exposure
was made possible through the NASA-Space Transportation system
utilizing the Space Shuttle Orbiter. The effects of micro-gravity
on living organism can only be tested over a long duration. Then,
reliable data can be obtained and applied where needed, possibly
assisting in the attempt to safely colonize Space. Many
material,man-made and natural,exhibit different characteristics
when introduced to weightlessness. Mechanical properties that are
associated with some materials become obsolete. The effects of
"gravitational pull" is found throughout the Universe at many
different levels. With the exploration of deep Space at our door
step, understanding microgravity is a new challenge to 'Today's
Engineer'. NASA made available the largest microgravity
laboratory known to man and now challenges him to explore it's
secrets. The study of processing materials in space can start
with experiments that are biological in nature. GAS-611 Project
will carry a small, self-contained, biological experiment into a
microgravity environment for a period of 120 hours. The payload
will be a colony of "Lampyridae", commonly known as the Firefly
or 'lighting bugs'. The ability of this beetle to produce light,
with an efficiency of 98%, will be evaluated in a micro-G
environment. The chemical process that occurs could be assisted
by Mother Earth's Gravitational pull and the very complex
tracheae system found within this species of Beetle. The ability
to place "Natures Light" next to a Star could only happen in
dreams, until NOW!
    Funding for this project is assisted by the sale of GENERIC
CADD drafting software.

Objectives: The Firefly in Micro-Gravity
    -What is the effect microgravity has on the ability of the
     Firefly to produce light? Can this effect be quantitatively
     measured?
    -Does microgravity effect the insects ability to function?
    -Is the larva of the Firefly effected by microgravity?
    -With the absence of thermal convection, is the Firefly
     affected in an way? Can this condition be determined?
    -What are the effects of the extreme G-forces introduced
     during the launch, on the firefly?
    -Does the Firefly respond to vibration in space the same way
     it responds on earth?
    -Is the Mating ritual the same in space as on earth?
    -Was mating successful? Are there any side effects after the
     space exposure?

    MICROGRAVITY: {17}The Lewis Research center in Cleveland
Ohio, has a fully equipped laboratory to conduct research in a
microgravity environment. Working in close proximity with NASA,
this facility can provide from 1 second to 20 minutes of
microgravity. The space shuttle program made available the
extended duration of microgravity that is needed to study
biological as well as materials and processing techniques. The
advantages to studying the effects of microgravity on earth
related materials is complicated by the required Space
Application Engineering needed to construct the Environment that
houses the experiment. The engineering techniques, used on earth
may not apply when subjected to a Zero "G" environment. The
effects of 'Shuttle Launch' can vibrate the entire Payload apart.
Electronics will self destruct if not properly designed for
temperature compensation. These are only a few of the design
parameters that surround a Space exposure experiment.
    The children of today are the engineers of tomorrow and the
future Space Application Engineers must be nurtured and
motivated,because they will be provided with the challenge to
become a 'Modern-Day Pioneer' in the 1990's. The responsibility
to future exploration can only be guaranteed if today's youth is
motivated and challenged.

    BIRTH OF THE GET-AWAY SPECIAL PROGRAM: In 1972,NASA was
given the assignment to develop a reusable space vehicle that
could carry large,heavy scientific experiments,and manufacturing
facilities into low earth orbit. The space shuttle that was
selected by NASA for the Space Transportation System is built
around a reusable space vehicle called the Orbiter with
expendable external tanks and two reusable solid rocket boosters.
The Orbiter, which is approximately the size of a DC-9 aircraft,
contains a crew compartment, that can accommodate up to 7 crew
members,and a 60 foot long by 15 foot diameter cargo bay,
designed to carry 65,000 pounds. The cargo bay doors will open in
orbit to permit a variety of experiments, investigations, and
space applications. {14} In accordance with national policy, NASA
must be reimbursed for providing launch services to non-NASA

|

customers. The pricing policy which NASA implemented is designed to recover the Space Shuttle operations cost over the defined 12 year operational lifetime of each Orbiter. The load factor per flight,based on either the length or weight of the payload, averages between 60% and 80%. This was the basis for establishing the pricing formula for major payloads.(10)The Shuttle reimbursement policy principle, recovers the projected average cost per flight whenever the cargo bay is 75% utilized ($1300 per lb). Since the remaining space was not required to produce revenue, the idea evolved that it could be used to provide opportunities to fly payloads of a small size, at a very low cost per pound (10) ($50.00 per lb); provided limited Orbiter services and resources such as power,crew support and deployment would not be required. (14)The objective for providing this opportunity, was to encourage the use of space research by educational institutions,small companies,organizations,and individuals that could not possibly afford the investment required to fly a major payload. These Payloads could Generate new Activities unique to Space,(GAS) thus providing the stepping stones to deployment of larger scientific or commercial payloads on future shuttle flights. To accomplish this objective NASA established the criteria that payloads of this class must be for scientific research and development purposes. NASA will not attempt to judge the scientific merit of a proposed experiment. All users will be required to furnish NASA evidence of scientific research and development intent and sufficient information for verification by NASA that the payload is for peaceful purposes and complies with applicable law and policy.

The Small-Self Contained Payload (SSCP) or Getaway Special program opened the Mysteries of the Universe to anyone who dared to challenge her.

EVOLUTION OF A PROJECT: (9) Working with the experimenters handbook a rough estimate of the thermal requirements can be obtained. (see Fig-A) 2.5 cubic foot container,with an insulated end cap,requires 15 Watts/hr. to maintain 26 degrees centigrade. Since the heating requirements will only be needed during the actual mission and a conservative estimate of 120 hours is established. A 1.8KWH battery pack will be needed for heating. The housekeeping requirements of the avionics,needed to control this payload will increase the battery pack to 2.0 KWH capacity.(Based on 5vdc@ 333ma continuous 120 hours). With this information the weight and volume of the batteries can be found in Graph B. Prior GAS payloads have used, NASA approved, Silver-Zinc (Ag-Zn) with much success. The weight of the battery pack is approximately 30 Pounds. The volume of these batteries will be 0.4 cubic feet,without containers and mounting hardware.
Structure weight estimate:Aluminum 6061-T6 (NASA approved)
    Density= 0.098 lbs/in3 (44.49 gm/in3)   (11)
    V=3.1415*R2*L   A=3.1415*D2/4   M=L*roh*3.1415*R2
The Shelves:Diameter= 19.0 inches   Thickness= 0.125 inches
    (these dimensions contingent on Stress Analysis)
L=0.125in   pi=3.1415   roh=0.098 lbs/in3   radius=9.5 in.

Mass s= 0.125*0.098*3.1415*90.25

Mass s=3.34 pounds for each shelf{using 4 shelves=13.89 lbs}
Side Brackets: Using a Symmetrical 'T' shaped bracket
{also contingent on stress analysis.}
Length=0.75 in.   Thickness=0.25 in.   Height= 14.00 in.
Mass b= (2*(0.250*0.75)*14.0)*0.098
Mass b= 0.5145 pounds each {using 6 brackets= 3.087 lbs
Total Structure weight: Mass t= 13.89+3.087
                        = 16.977 pounds   {occupying 0.1 cubic feet}
The experiment recording system will be a 35mm camera with a
close-up lens,autowinder and a special 250 film pack. The film is
used to record numerical data via LCD display in the field of
view of the camera. This method is a simple and permanent form of
data storage. This system may be replaced by a video camera /
recorder if the weight limit is still maintained.

The avionics and recording weight is estimated to be 3.0
pounds. Actual weight of the electronics package is not
calculated for this presentation. The weight of the recording
system was determined by the shipping weight of a complete
AE1-Program camera outfit from a mail order house.
Weight of the Enviro-Chamber: Structure= 4 Shelf ===> 13.890
Pounds   6 Brackets=>   3.087   "

		Total ===>	16.977	"			
Batteries=			30.0	"	Weight Limit	60.0	lbs
Recorder & Avionics			3.0	"	- total	50.0	"
Total SBR			50.00	"	Enviro-Chamber	10.0	"

The Get-Away Special program has a size and weight
parameters that are within the guidelines of the space
transportation system. The model presented is the first pass
attempt to establish the direction needed to obtain the required
design for reliable payload results. The smallest payload
parameter, offered by NASA, was selected as the starting point
for this project. {9} Payload Envelope Parameters:Container Size
19.75" x 14.13" Weight limit   60 lbs---- 2.5 cu ft.
The payload will be completely self-supporting,with 3 electrical
controls to be operated by the Astronauts. {9} The NASA supplied
container,that houses the payload, is made of aluminum with an
insulation on the exterior. The mounting plate is 19.75" x 0.625"
thick aluminum with purging ports and can not be altered by the
experimenter. The inside of this container will maintain 1
atmosphere of dry air throughout the entire mission. This
experiment requires an environment that can sustain the life of
insects for 15 weeks. The total time in a microgravity state will
be 4 to 7 days. This will occur approximately 75% into the 15
week mission. Temperature of the enviro-chamber will be 26
degrees centigrade for the entire 15 weeks. Strip type heaters
will be activated by a high/low thermostat to maintain this
temperature. In the event the temperature rises too high, then a
small fan will be activated, by the thermostat, inside the
avionics bay.

```
      ENVIRO-CHAMBER DESIGN:Based on a 10 pound limit and a
remaining volume of:(Fig-C)
            Structure              = 0.1 cubic feet
            Battery                = .5    "    "  (19"dia.x 3"high)
            Recorder/Avionics      = .82   "    "  (19"dia.x 5"high)
                                   ------------------
            total SBR              = 1.42 cubic feet

            Volume limit           = 2.50 cubic feet
            minus total SBR        = 1.42   "     "
                                   ------------------
            Enviro-chamber         = 1.08 cubic feet
The chamber construction will be made of wood for this model.
It's dimensions are 12" x 12" x 5" Square.
White Pine Density = 0.0156 lbs/in3 (11)
      Sides: 5"* 12"* 1"= 60 in3* 2 = 120  in3*0.0156= 1.872 lbs
             5"* 10"* 1"= 50 in3*2  = 100  in3*0.0156= 1.560 lbs
Top &  Bottom  : 10"* 10"* 1"= 100 in3 * 0.0156 * 2= 3.120 lbs
                                                    ------------
                              Total          = 6.552 lbs
The inside of the chamber will be lined with moist earth. The
soil will be retained in a 'mesh' envelope and will have the
necessary Nutrients to sustain the insect's diet. For this model
the density of Moist Earth=0.0451 lbs/in3  (11).
Plates: 3"* 10"* 0.25"=7.5 in3 *4 = 30 in3* 0.0451 = 1.353 lbs
        10"*10"* 0.25"=25 in3 * 1 = 25 in3* 0.0451 = 1.128 lbs
(bottom only)                                      ------------
                              Total          = 2.481 lbs
Weight of the Wood structure and the lining plates = 9.03  lbs
      The inside of the walls will have 3 slots milled 0.5"wide x
10.0" long x 0.5" deep to provide a natural 'Crevice'(1)habitat
the insect is familiar with. The weight of the enviro-chamber is
reduced by the slots and the opening of the Camera system
by 0.935lbs. These 'roads' will also be linked vertically and
will be constructed such that when traveled the insect will be
directed to the open chamber where the recording system can
document their activity. The bottom plate  will have a water
seeding system, consisting of a simple 'Wick' laced within the
plate. This will provided needed moisture for some humidity. (18)
It must be noted that the dry air used by NASA has a Dew point of
-76 degrees Fahrenheit. This condition is not desirable inside
the Enviro-Chamber as it could cause dehydration.
      In the center of the open chamber is a four sided pyramid,
coated with mirrors to provide the 'window' to observe the inside
of the entire chamber. The water seeding bag will be housed by
this structure. The water seeding bag requires a special valve
that prevents it from emptying at launching because of the large
'G' force imposed on it. A heater will be mounted on the bottom
side of the top cover and will be controlled by a thermostat near
the center of the chamber. Additional heaters will maintain the
outside temperature of the enviro-chamber. This method of
maintaining the payload temperature will reduce the thermal
gradient of the internal payload structure and transfer the
```

additional stress to the NASA supplied canister. A composite
material will be used to further insulate the remaining volume of
the Enviro-Chamber Bay. Weight is the determining factor.
COSTS:Design,and Construct or Lease the Equipment? The success
of an individual is determined by that individual's ability to
find a need and fill it. With the introduction of the GAS
program,the emergence of unique support groups have evolved. The
GAS Program is a small part of a very large unit called NASA. The
program is structured to accommodate the experimenter and allow a
simple idea to expand to a full project without the red tape
associated with a typical Military space experiment. The
redundancy has been left out. There still are many requirements
for a GAS project. The safety manual is 200 pages not counting
the continuous flow of mail that is termed 'associated' with the
GAS program. The money charged,by NASA ($3000.00 for this
Project) for it's role in a project,can be considered to be the
best-deal-in-town, because the support provided by NASA is far
greater than the actual charges. To the new user this may not be
evident when first introduced to the program. Many times NASA
officials will verify a particular part or material to assure it
is safe to use in the environment of space. The key too pushing a
project through the portholes of NASA Safety program is to use
materials and methods already approved. Re-inventing the
'so-called wheel' methodology is not a cost effective thing to do
when designing a Space exposure project. The cost start to
escalate when one tries to shrink a full size 'earth environment'
into 2.5 cubic feet with a maximum weight of 60 lbs. {9} The
cost of Silver-Zinc batteries for this project,based on 2.0 KWH
will be about $1800.00 (1979-dollars).
A typical, commercially available, Data recorder ranges from
$1500.00 to $55,000.00 and not only carries a hefty price tag but
weighs a TON. The INDIVIDUAL-OUT-OF-POCKET raw cost to complete
this project is $25,000.00. With the support of 'sponsors' this
projection could be on the high side.
     There is an alternative, three companies will provide their
expertise and lease an experimenter a complete payload
integration service,tailored to the user's requirements. The
paper work with NASA is also handled so the user can concentrate
on the Experiment.
Who's Who: Vendor   Cost for services
          Instrumentation Technology   Start at
          Associates(ITA-Exton,Pa)------> $55,000.00
          Getaway Special Services------> $35,000.00 to
          Bellevue,Washington $50,000.00
          MBB-Erno   ----->   Start at
          Germany $100,000.00
          Quartic Systems   Has an Electronic computer/recorder
          Salt Lake City   that draws 15 milliwatts. (NICE)
     The dollar value may be considered high when first reviewed
but for a ONE TIME experiment these services could save much time
as well money. The experimenter that establishes the requirement
of multiple flights would reuse his original Payload canister.

GET AWAY SPECIAL
SMALL SELF-CONTAINED PAYLOADS
2 1/2 FT³ CONTAINER WITH INSULATED END CAP

FIGURE A

TOP

BATTERIES   3"

ENVIRO-
CHAMBER   6"

RECORDER/
AVIONICS   5"
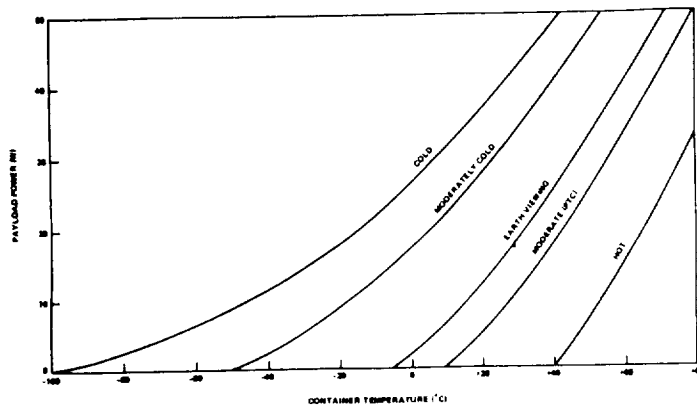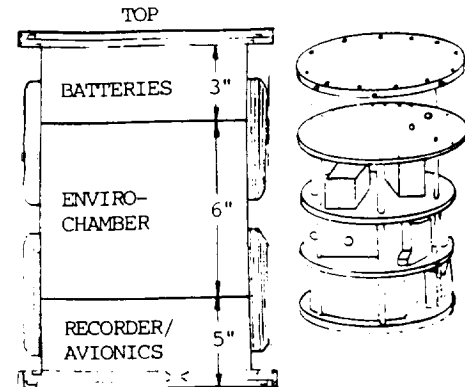
FIGURE C

GET AWAY SPECIAL
SMALL SELF-CONTAINED PAYLOADS
BATTERY DATA

CURVES:
1. SMALL, COMMERCIAL QUALITY NI-CAD BATTERY PACKS.
2. MIL SPEC, AEROSPACE NI-CAD BATTERY PACKS.
3. OFF THE SHELF AG-ZN
4. HI-RATE AG-CAD
5. LO-RATE AG-CAD
6. NI-ZN
7. LI-CF
8. SPECIAL ORDER AG-ZN —

R CURVES ARE ESTIMATED COSTS
FOR GFE SILVER AND SILVER
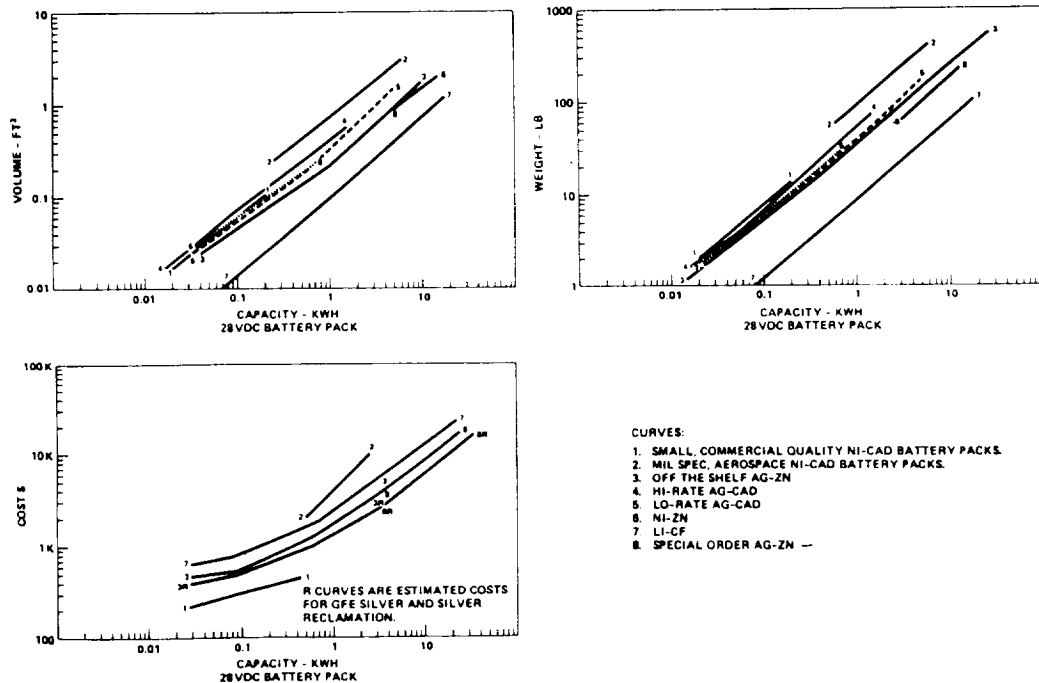RECLAMATION.

FIGURE B

71

GAS-611 Project FIREFLY References:
A manual of Common Beetles of Eastern North America......595.7 d
     By Elizabeth S. and Lawrence Dillon Vol 1
1   Dover publications,inc. New York 1972
     page 248 (Cedar Crest High School)
Get Away Special Safety Manual
     By NASA Goddard Space Administration
8   November 1983
Gas-Small Self-Contained Payloads...Experimenter Handbook
     By NASA Goddard Space Administration
9   Special Payloads Division
     July 1984
Get Away Special Experimenter's Symposium
     By Proceedings of a Symposium held at NASA
10   Goddard Space Flight Center
     Greenbelt,Maryland
     October 8-9, 1985
Mark's Standard Handbook for Mechanical Engineers
     By Baumeister-Avallone-Baumeister
11   Eight Edition
     McGraw-Hill New York
Statics and Strength of Materials......Third Edition
     By Jensen and Chenoweth
12   McGraw-Hill New York
Small-Self Contained Payload Overview
     By Donna S. Miller
14   NASA Office Of Space Transportation Operations
Safety Policy and Requirements
     for Payloads using the Space Transportation System (STS)
15   NHB 1700.7A
     NASA-Washington,DC 20546
     DEC-9,1980
Microgravity Materials Science Laboratory
     NASA-Lewis Research Center
17   Cleveland, Ohio 44135
     September 1985
     Services available to Study Microgravity
The Final Report of Orbit 81: An investigation into the cause of
     death of the Colony of Ants June 18,1983
18   by Students of Camden High School and
     Woodrow Wilson High School

ACCELERATION GROUND TEST PROGRAM TO VERIFY GAS PAYLOAD NO. 559
STRUCTURE/SUPPORT AVIONICS AND EXPERIMENT STRUCTURAL INTEGRITY

Paper to be Presented at the 1988 NASA GAS Symposium

John M. Cassanto
Valerie A. Cassanto
Instrumentation Technology
Associates Inc. (ITA)
Malvern, PA 19335 USA

ABSTRACT

Acceleration ground tests have been conducted on GAS Payload 559 to verify the structural integrity of the structure/support avionics and two of the planned three flight experiments. The ITA Standardized Experiment Module (ISEM) structure was modified to accommodate the experiments for P/L 559. The ISEM avionics consisted of a heavy duty silver zinc power supply, three orthogonal mounted low range microgravity accelerometers, a tri-axis high range accelerometer, a solid state recorder/programmer sequencer, and pressure and temperature sensors.

The tests were conducted using the Gravitational Plant Physiology Laboratory Centrifuge of the University City Science Center in Philadelphia, PA. The launch-powered flight steady state acceleration profile of the Shuttle was simulated from lift-off through jettison of the External Tank, which occurs at the maximum axial acceleration load in the ascent trajectory of approximately 3.0 g's. Additional tests were conducted at twice (2X) the nominal Shuttle predicted powered flight acceleration levels (6 g's) and an over-test condition of four times (4X) the powered flight loads to 12.6 g's.

The present test program has demonstrated the value of conducting ground tests to verify GAS payload experiment integrity and operation before flying on the Shuttle. This test philosophy will provide the maximum return of zero g data from the GAS program.

1.0 INTRODUCTION

Payload 559 will be flight ready for a Get Away Special Cannister in 1989. The original payload consisted of three basic experiments: the prime experiment (No. 1), Mr. Ivan Vera's Membrane Casting Apparatus, two protein crystal devices experiment (No. 2) sponsored by the Bioprocessing and Pharmaceutical Research Center (BPRC) in Philadelphia, PA, and a protozoa growth experiment (No. 3) sponsored by the Hispanic Community. Acceleration ground tests using a centrifuge were conducted on the ITA Standardized Experiment Module (ISEM) which consists of an aluminum aerospace structure and support avionics (power supply, recorder/sequencer, low and high range accelerometers and pressure and temperature sensors) as shown in Figure 1. Experiments 2 and 3 were mounted to the ISEM during the ground tests, however, Experiment No. 1 was not

available and consequently a mass simulator was utilized to ballast the payload to 200 lbs. P/L 559 will be reconfigured from the above test configuration due to Experiments 2 and 3 being dropped by their sponsors.

2. ISEM AVIONICS

The following support avionics described below were integrated into the basic ISEM structure for the acceleration test program.

- 3 Schaevitz low range ±0.25 g accelerometers
- 1 high range ±20 g three axis Entran accelerometer
- 1 0-20 psia Kulite pressure transducer
- 1 Tattletale recorder/data logger
- 1 Onset computer/recorder/data logger/sequencer
- 6 Yardney silver zinc LR90 cells
- One stainless steel battery box

In addition, signal conditioners and junction boxes were fabricated and mechanically integrated to the structure. The purpose of the signal conditioner/junction boxes is to provide commands, distribute power, and record data.

3.0 TEST PROGRAM DESCRIPTION

The test program was designed to simulate the Shuttle launch/powered flight steady state acceleration profile. The launch profile was simulated out to approximately 530 seconds which corresponds with the separation of the External Tank and an axial load of approximately three (3) g's. The Shuttle acceleration levels are less from this point on in the trajectory to orbit. The ISEM was mounted to the centrifuge using the standard GAS interface. The unit was repositioned on several runs such that the loads could be applied to three orthogonal axes. Functional tests were performed on each experiment and each subsystem of the avionics after each centrifuge run.

4.0 FACILITY DESCRIPTION/TEST SET UP

The University of Pennsylvania Gravitational Plant Physiology Lab centrifuge is a dedicated acceleration research facility that was used for the program. Figure 2 presents a photograph of the centrifuge showing the ISEM mounted inside the test gondola. It should be noted that the ISEM was mechanically mounted to an adaptor plate on the gondola identically to the attachment scheme defined by NASA for Shuttle operations, i.e., a 19 inch bolt hole circle. The centrifuge contained accelerometers mounted adjacent to the top and the bottom of the ISEM.

A control room was located adjacent to the centrifuge room where TV monitors and VCR recorders were used to observe and record the module during the run. In addition, the instantaneous

74

acceleration levels were recorded for "real time" assessment of the test results and the final data analysis.

5.0   TYPICAL RUN SEQUENCE/TEST PROCEDURE

Pre-test photographs were taken of the payload prior to each run. Functional tests were then conducted on the avionics and the experiments. Voltages of each sensor were monitored and recorded. Pressure and low range accelerometers were stimulated and the responses recorded. The experiments were energized and the motors run in each direction.

The recorder-data logger was then activated and the centrifuge started. The ISEM module was observed by the TV camera mounted on the hub of the centrifuge, and the instantaneous real-time read out of the centrifuge accelerometer levels were monitored and recorded.

After the centrifuge was shut down and ceased to rotate, the onboard recorder was de-activated and the ISEM visually inspected. Post test photographs were taken to document structural integrity of the module and components. Functional tests were then conducted again on each avionics component, and on the experiments to verify that they operated properly after being subjected to the acceleration environment.

The module was then taken out of the cradle to change the orientation for the next run as shown in Figure 3 and the entire procedure was repeated.

6.0   TEST RESULTS

Figure 4 presents the results from the first test which was a standard Shuttle (3 g) run. The difference in readings between centrifuge accelerometers 1 and 2 was due to location differences on the arm. The ISEM accelerometer shows good agreement with the centrifuge data after being biased to one g. Figure 5 presents data for the ramp function to 12.6 g's (4x Shuttle loads). It should be noted that the ISEM flight accelerometer (Entran tri-axis) tended to drift during the entire test series.

A comparison of the Shuttle acceleration profile from flight data with two centrifuge runs (1X and 2X Shuttle) using the ISEM data is shown in Figure 6. This comparison demonstrates that centrifuge facility provides a good simulation of the Shuttle acceleration flight loads.

All of the avionics performed well during this test program with the exception of the three axis Entran accelerometer which tended to drift. As a result of this test program, the Entran acceleromoter is being replaced on Payload 559.

The BPRC crystal growth experiment showed a potential failure mode which has been corrected for the actual flight. Finally, the power supply provided ample power for the test program, however, the Yardney cells "leaked" when subjected to the 12.6 g acceleration ramp function. This points out that orientation of these cells is important when designing a GAS payload.

7. CONCLUSIONS

The following conclusions were reached as a result of this test series:

A. The centrifuge facility provided a good simulation of the steady state acceleration load profile during the launch ascent portion of the Shuttle trajectory.

B. The ISEM structure, avionics, and MPS experiments survived the max loading condition, (12.4 g's) and all electronics and mechanical components successfully operated and passed functional tests after the environments.

C. The three axis high range accelerometer to monitor launch and re-entry loads was found to drift to an unacceptable level during the test program. Accordingly, the accelerometer will be replaced prior to shipment of the payload.

D. A potential failure mode of one of the MPS experiments (protein crystal growth) was identified and subsequent modifications made to the hardware to eliminate the potential failure mode.
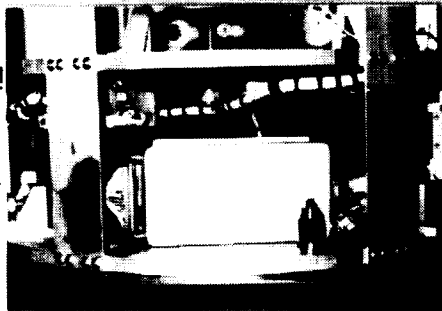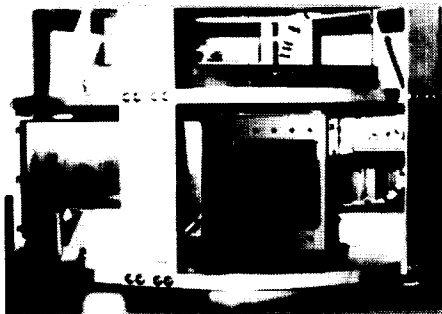

8. CONCLUDING REMARKS

The present test program has demonstrated the value of conducting ground tests to verify GAS payload experiment integrity and operation before flying on the Shuttle. This test philosophy will provide the maximum return of zero g data from the GAS program. Subsequent additional tests are planned for Payload 559 after reconfiguring some of the experiments. The reconfigured payload will be subjected to the Shuttle vibration environment prior to shipment to NASA.
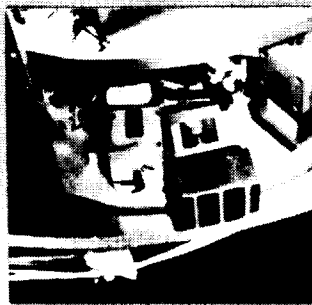

9. ACKNOWLEDGEMENTS

|

INSTRUMENTATION
TECHNOLOGY
ASSOCIATES

Figure 1

77

Instrumentation

Power supply

Figure 2   Centrifuge with Test Gondola

Figure 3   ISEM Being Repositioned to Change Load Vector

78

O ISEM ACCELEROMETER

△ CENTRIFUGE ACCEL No. 1

X CENTRIFUGE ACCEL No. 2

ACCELERATION LEVEL~G's

T~TIME~SECONDS

NOTE: ISEM DATA BAISED TO ONE (1) G

— — 1.0 G

Figure 4.   Centrifuge Test Data for Normal Shuttle Loads

ACCELERATION LEVEL~G's

— — — CENTRIFUGE ACCEL No. 2

— — — — CENTRIFUGE ACCEL No. 1

O ISEM ACCELEROMETER

— — — — 1.0 G

T~TIME~SECONDS

Figure 5.   Centrifuge Test Data for 4X Shuttle Loads

79

COMPARISON OF U OF P CENTRIFUGE GROUND TEST DATA
WITH SHUTTLE FLIGHT DATA FOR LAUNCH ASCENT
ACCELERATION PROFILE

U OF P CENTRIFUGE

ITA ISEM RUN NO. 1

SHUTTLE FLIGHT DATA

ITA ISEM RUN NO. 2

ORIGINAL PAGE IS
OF POOR QUALITY

U OF P
CENTRIFUGE
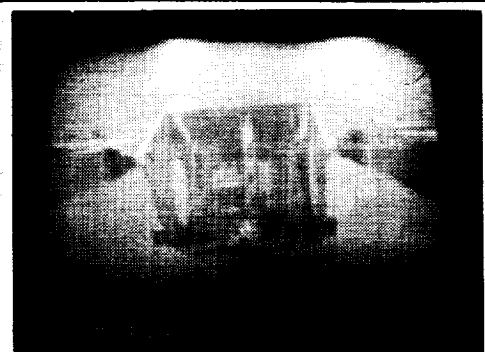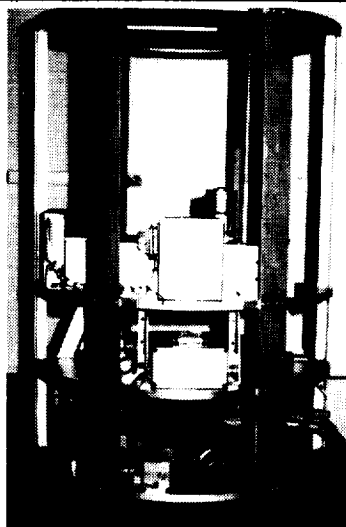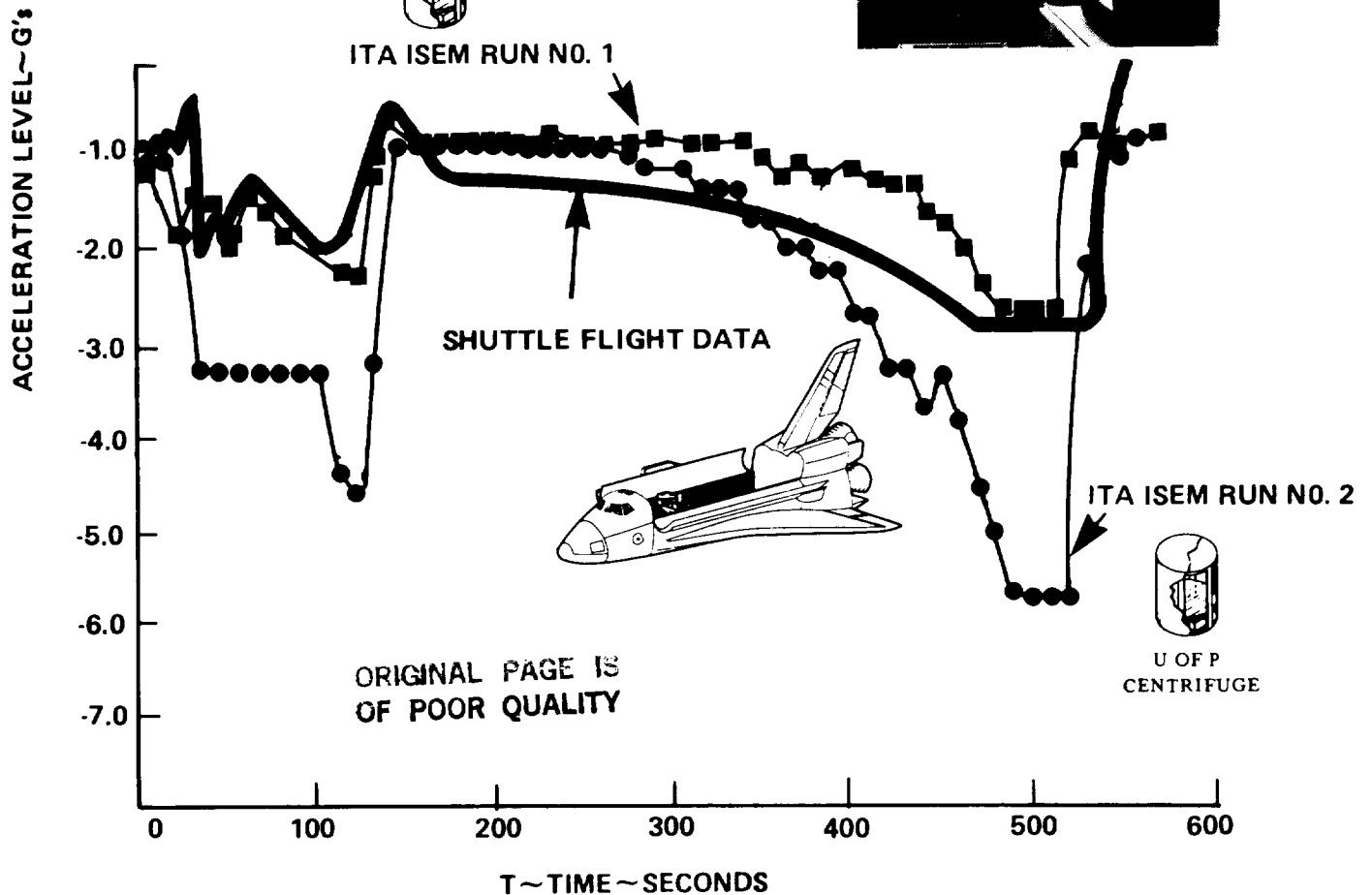
DATA SOURCE: ITA CENTRIFUGE TESTS, JULY 1986

Figure 6

UTILIZATION OF SPRAY ON FOAM INSULATION FOR
MANNED AND UNMANNED SPACECRAFT AND STRUCTURES

BY

Thomas M. Hancock III

ABSTRACT

This paper will explore the idea of using spray on foam insulation as a passive thermal and micrometeorite protection system. Examples of its application, utilization and benefits are addressed.

When the United States begins the development of large space structures (Space Station, Lunar base, Mars missions and large space factories), there will be two requirements common to all these designs: the need for a lightweight and passive micrometeorite and thermal protection system. One such possible solution to both these requirements is a stable, strong type of spray on foam insulation.

The benefits of applying an exterior coating of foam insulation can be:

1. The foam can provide a thermally stable shield that can assist in reducing the strain on traditional space radiator systems. It can also act as a passive thermal guard, allowing a greater fault tolerance if the standard system should fail.

2. The foam can act as an ablative shell diminishing the effects of natural and manmade debris striking the structure.
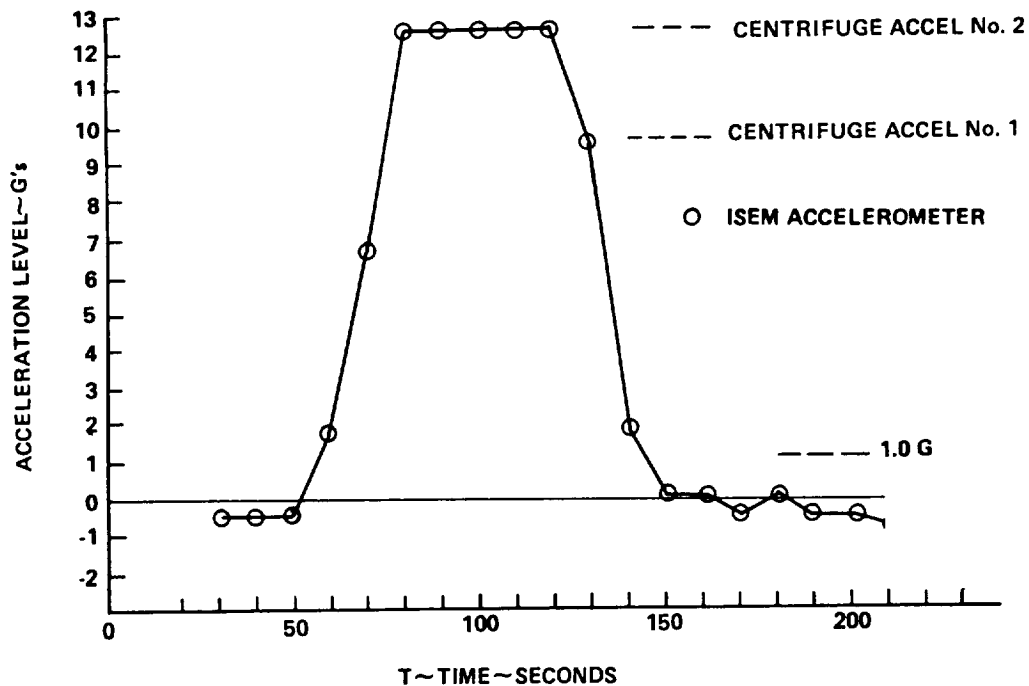
3. The foam can provide a lightweight passive shield with a general weight of ½ ounce per 1ft2. This is highly attractive from the position of design.

4. Cost: a spray on foam system can represent a significant cost-effective design.

5. Maintenance: the maintenance of such a system will be minimal and simple to carry out.

6. A stable material that does not react when exposed to Earth or Lunar space environment. (The Thermal Blanket insulation originally developed for the Galileo Jupiter mission was found to deteriorate when exposed to atomic oxygen in low Earth orbit.)

When one considers that current solutions to this problem include Armored Skins, Thermal Blankets and Louvers, the obvious and practical applications of foam insulation in fulfilling each of these requirements represents a simple, complete and cost-effective method for meeting the requirements of thermal and meteorite protection.

—

COMPUTERIZED MONITORING AND CONTROL OF EXPERIMENTS IN SPACE

Thomas V. Janisch
Project Manager; Villanova University
Space Shuttle Experiments Program
Graduate Student; Villanova University

ABSTRACT

The Villanova University GAS experiment apparatus is divided into three major subsystems: the boiling experiment apparatus, the polymer experiment apparatus and the computer subsystem. This paper will be limited to a discussion of the computer subsystem.

The function of the computer subsystem is to provide data acquisition and control system support to the experiments. The computer subsystem will provide high availability, low power consumption, and highly reliable data retention. The general layout of the subsystem provides for redundant processing units, control modules, and multiple data acquisition modules.

The two redundant processing units are identical. Each processing unit will be self checking and will contain the same program code. Each processing unit will be composed of a microprocessor, control logic, PROM, RAM, non-volatile memory, timers, self check logic, and data ports to the data acquisition and control modules. One unit will control the experiment while the other shadows the primary unit operation. The data ports are generic, this yields increased flexibility in use with the current experiments, as well as with future experiments.

The data acquisition module gathers data from the experiment. The data is transferred to the redundant processing unit in digital form. The control module will receive command data from the redundant processing unit. The control module validates the data, decodes it and executes the command.

The Computer Subsystem

The computer subsystem is designed so that it can be used for any GAS experiment to control and monitor a wide range of devices and sensors. It is also designed to operate in the harsh environment of space. The concerns for the GAS canister environment include radiation, large temperature swings, and battery power. In the boiling experiment, the computer will control devices such as a simple heating element, a stepper motor, 35mm cameras, subsystem coolant pumps, and will monitor time, temperature and pressure. In the polymer experiment, the computer will control the chemical release mechanism and monitor time and temperature. The two experiments are designed to run at different times during the space shuttle's flight. The computer will also monitor temperature inside the GAS canister.

The computer subsystem will provide high availability by having redundant capability. The redundancy will be incorporated into two processing units and duplicate monitoring and data acquisition modules as seen in Figures 1 and 2. The power consumption will be minimized by using low power Complementary Metal Oxide Semiconductor (CMOS) digital components. Highly reliable data retention will be provided by storing a copy of the data in nonvolatile memory with error detection and correction on each of the processors and also by placing the data on peripheral storage via a very small printer or information display panel with a camera. In addition to the redundant element of the system, the digital component used in the system will be "Industrial" grade, which is one grade better than is found in a typical home computer.

Identical redundant processors will each be composed of the following: a microprocessor, control logic, PROM, ROM, nonvolatile memory, timers, self check logic, and data ports. The microprocessor will be a CMOS version of either an Intel 80X86 or Motorola 680X0 processor family. The choice of processor will depend on throughput required and availability of development tools. Most of the control logic will be composed of CMOS programmable array logic (PAL) and interrupt controllers. The flight version of the PALs will be non-alterable, while the development version will be an erasable version. Like the PALs, the PROM will also be CMOS and for the flight hardware be non-alterable. The RAM will have an error detection and correcting code added to the data, allowing most data errors to be automatically corrected. The nonvolatile memory will be an Electrically Erasable Programmable Read Only Memory (EEPROM) or a similar device. The data written to nonvolatile memory will also have an error correction code associated with it. The experiment timers will be backed up by the self check logic.

The self check logic will include "deadman" timers and address range check logic. The "deadman" timers will insure that the processor does not get caught in an infinite loop because of a software error or memory upset. Memory upset can occur when radiation hits a memory cell inside a semiconductor chip. Each processor unit contains two "deadman" timers. One "deadman" timer monitors the unit's execution and is connected to the processor's non-maskable interrupt. The

other "deadman" timer monitors the execution of shadow processing unit and is connected to the programmable interrupt controller. A connection to the non-maskable interrupt which can not be postponed allows any processing to be stopped. The primary processing unit can postpone dealing with processing problems with the shadow unit, if necessary. The reason for the delay in dealing with the shadow processing unit results from the need of the primary processing unit to process events associated with the experiment in a timely manner. The address range check logic will protect against software errors and processor internal memory upsets by causing a non-maskable interrupt to occur.

Communication between the processing units to and from the control modules and data acquisition modules will provide for reliable communication and failure isolation. The ports on the processor board will have bidirectional data transmission and each port will operate either as a serial or parallel data path. The electrical interface will use a standard interface such as RS-232 or Centronics. To off-load work from the main central processing unit (CPU), a micro-controller, such as an Intel 8051, will be used to control the communication interface. Each port can be configured so that it may be used either as a port to a control module or a port to a data acquisition module.

The control or data acquisition module will be redundant. The interconnection of the modules to the processors will be pairwise as shown in Figure 1. The modules are interconnected to enable the module controlled by the operational processor to override the other module in the event that a processor shuts down. Data flows in both directions between the experiment and redundant modules.

A control module, which controls a stepper motor for example, will contain all the items needed to control the motor. The module will contain communication interfaces, logic to decode data coming from the processor, and logic to control the motor. The communication interfaces will go to a processor unit or to the redundant control module. When in operation, a processor unit will send a command to the control module. The command is then decoded by the control module which causes the stepper motor to move in the manner indicated by the command.

A data acquisition module used to collect temperature readings will read and transmit the data to a processor unit. The module will contain communication interfaces, the logic to digitize the temperature data and logic to control transmission of the data to a processor unit. When in operation, a processor will request that the module read the temperature. The data acquisition module will then, via an analog to digital converter, convert the analog electrical signal coming from a temperature sensor to a digital number which will then be transmitted to the requesting processing unit.

The PROM-resident software will control the experiments. It is the software that will coordinate a heater's output with the measurement of the corresponding temperature rise. The software will also have to configure the communication ports to the control and data

acquisition modules. The software will have control over which experiment is currently running and will switch over after the first experiment is completed. The system software can not be fully designed until all of the devices and conditions that need monitoring are known.

The main improved capability of the computer subsystem over the typical home computer is that the subsystem will incorporate many redundant features, low power consuming CMOS components, as well as higher grade semiconductor components. The many redundant features of the system and higher grade components significantly lower the possibility that the subsystem will be unavailable. The extensive use of CMOS components will lower the subsystem's power requirement thereby reducing the number of batteries needed to supply power. The highly reliable data retention is insured by storage of multiple copies of the data in two sets of nonvolatile memory with an error detecting and correcting code attached; data will also be saved on peripheral storage.

Acknowledgements

Module Connection Diagram
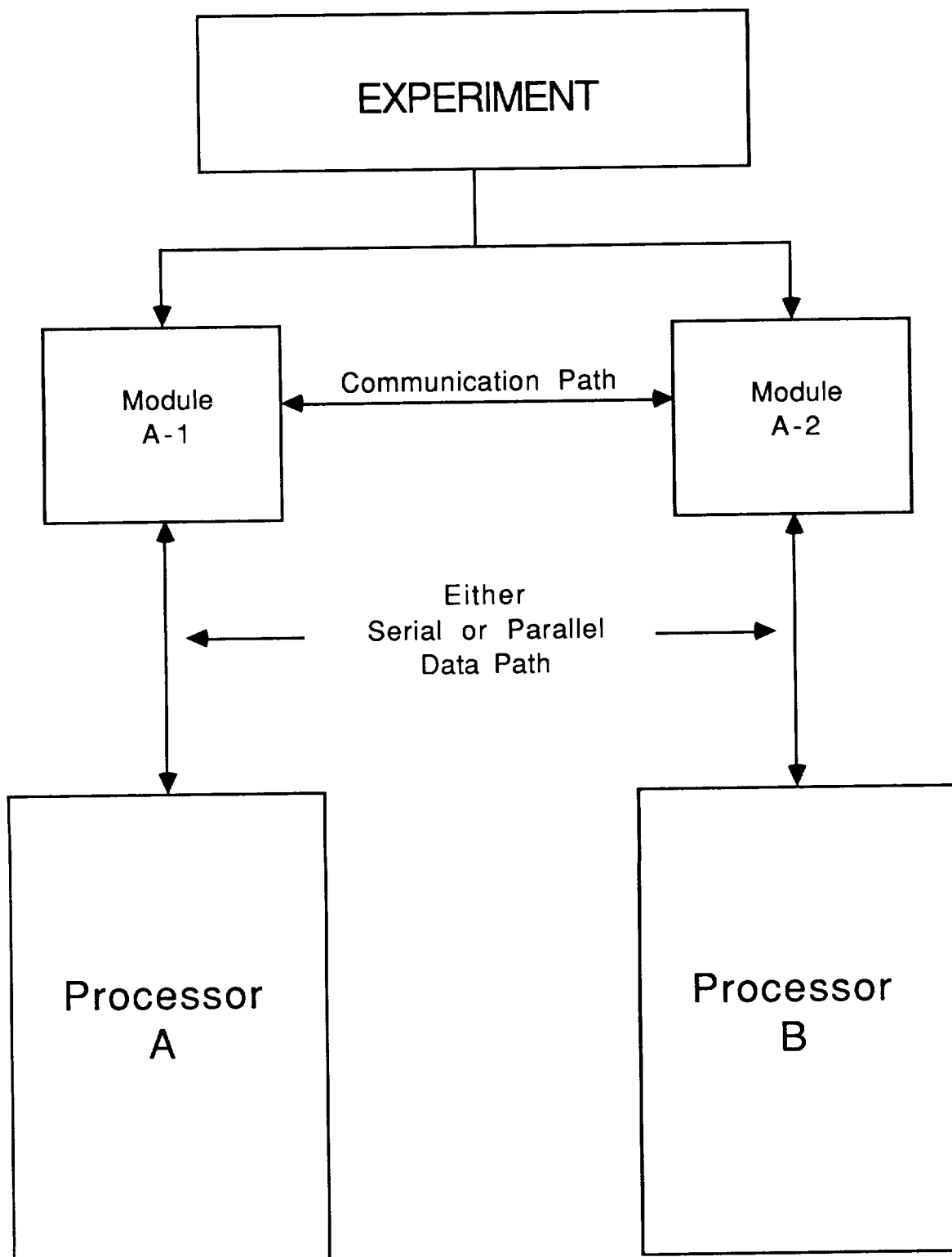
Figure 1

Computer Subsystem Block Diagram
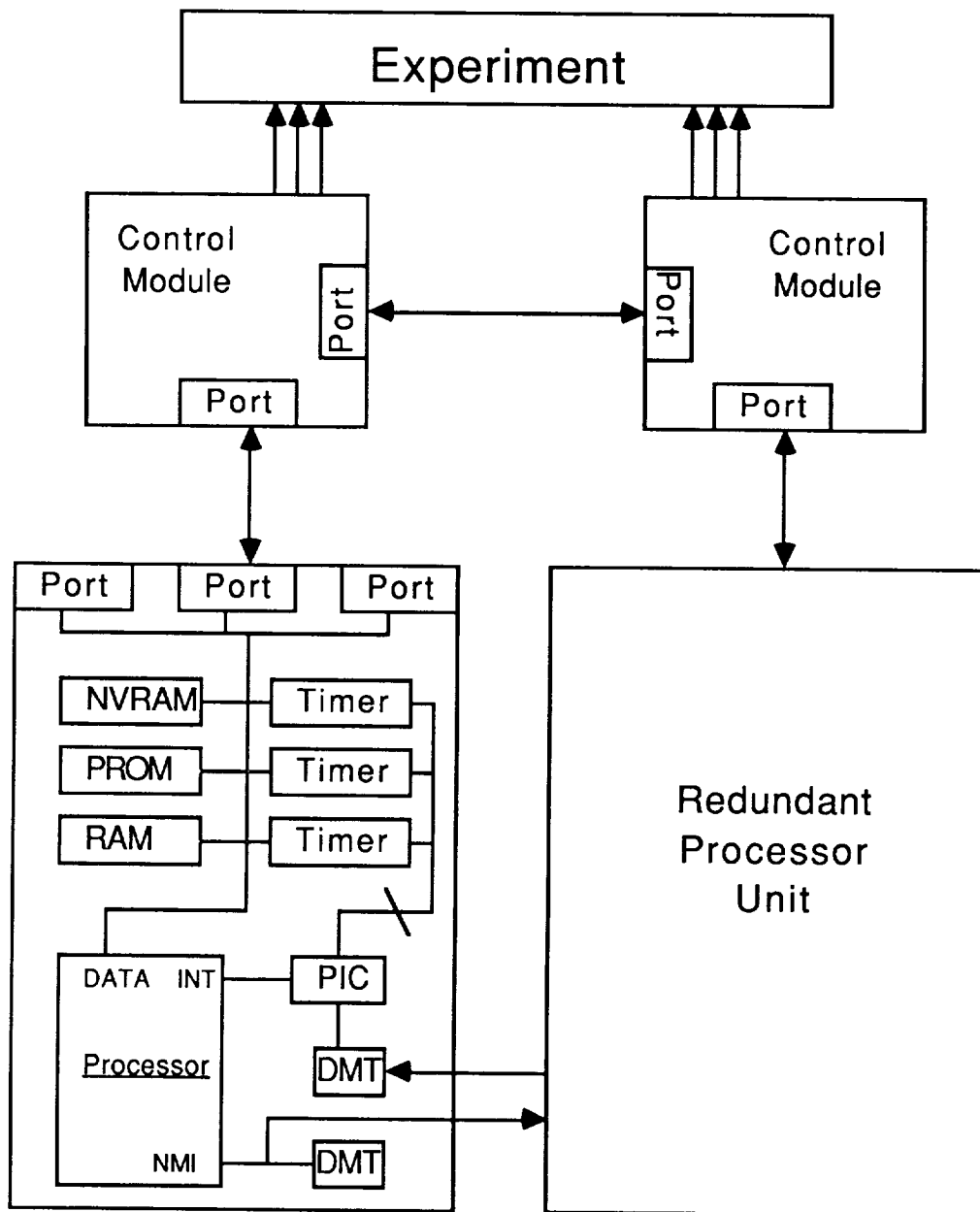
Key:

DMT - deadman timer INT - interrupt NMI - nonmaskable interrupt NVRAM - nonvolatile RAM	PIC - programmable interrupt controller PROM - programmable read only memory RAM - random access memory

Figure 2

THE POTENTIAL OF A
G.A.S. - CAN

WITH

PAYLOAD G-169
ROCKWELL INTERNATIONAL CORPORATION / CAL POLY SPACE SYSTEMS
SPACE WELDING PROJECT

WRITTEN AND PRESENTED AT
THE 1988 NASA GET AWAY SPECIAL EXPERIMENTS SYMPOSIUM
BY
DAVID TAMIR
PAYLOAD MANAGER: G-169
PRESIDENT: CAL POLY SPACE SYSTEMS

FAYSAL A. KOLKAILAH - PROJECT ADVISOR
AERO DEPARTMENT, CAL POLY STATE UNIVERSITY

ABSTRACT

As we venture into space it becomes necessary to produce, expand and repair structures for our housing, research and manufacturing. The microgravity-vacuum of space challenges us to use construction options which are commonplace on Earth. Cal Poly Space Systems and Rockwell International Corporation have jointly taken on the challenge of construction in space using the option of welding. However, the conquering of such a challenge through a joint cooperation between students and industry is made possible by NASA's Get Away Special Small Self-Contained Payloads Program.

The potential of a Get Away Special (GAS) canister is proven through the development of a dream into a reality. The dream is space based construction, expansion and emergency repair via welding. And the reality is presented in this paper.

BACKGROUND

Why weld in space ?

In recent decades, welding has become a dominant process for building metal structures on earth. The rapid and continuing growth of welding applications is due to the inherent advantages of this joining method over mechanical and adhesive techniques. Such advantages as high joint strength, reduced mass, improved hermetic sealing, increased flexibility in design of structural joints, quicker application to unique scenarios, and consequently reduced overall cost are dramatic on earth but become even more attractive in space.

The high cost of shipping building materials into Earth's orbit is a difficult and limiting burden. Any potential mass reductions have to be utilized; from design through fabrication. Welding allows for mass reductions by eliminating the need for oversized mechanical joints. The extra components and increased gage of parent members at the mechanical joint are necessary to provide means of joining with acceptable strength [1]. Alternatively, for welded joints the most required could be a minimal amount of filler metal for bridging gaps during fit-up problems.

Limited dexterity available to the astronaut in extra-vehicular activity (EVA) requires expensive specialized mechanical connectors. Even though the development of an EVA welding system would not be cheap for the astronaut with the same limited dexterity, in the long run the overall cost of numerous and diverse mechanical connectors would far outweigh the cost of a versatile space welding system.

Meteors and space debris pose a growing collision hazard as we advance to inhabit space. When setting this hazard in a vacuum, the repair of damaged structures containing human life becomes significantly more critical than in the terrestrial environment. Repair time is of the essence. Hence, the versatility of a joining process must be maximized. Welding is far more versatile than any other metal repair method. Welding requires relative minor surface preparation of the component to be repaired. While mechanical repair could require machining preparation and corresponding tools, specialized fasteners, hermetically sealing adhesives, and consequently a great deal of unaffordable time.

In conclusion, welding is a primary candidate process for construction, expansion and emergency repair of space based structures.

Which welding method should be used ?

Any welding process developed for use in space should be amenable to both manual and automatic use and have the extra versatility to work inside pressurized life supported quarters as well as in the outside vacuum. The process must have reasonable productivity; it must be efficient in utilization of energy; it must work on a variety of materials (i.e. light metals, refractory metals and composites); it should provide capability in construction, expansion and repair; it should be forgiving of joint mismatch or fit-up problems; and it should use a minimum weight of consumable materials [1]. However, to choose one single welding technique which maximizes each of the so many requirements for a space welding process is impossible. Thus, it is necessary to start with the method which possesses the best overall combination of properties.

Gas Tungsten Arc Welding (GTAW), better known as Tungsten Inert Gas (TIG), has been selected as the welding process to best fulfill the requirements of a space welding system. When GTAW is compared with its best adversary, electron beam welding, GTAW proves to have a superior potential in manual operations and adaptability to imprecise fit-up problems with structural members [1]. Other draw backs of electron beam welding include the need to shield the astronaut from X-ray radiation produced during this joining process, and the need for a vacuum which is impractical for welding inside life supported pressurized quarters. Also, the energy requirements of a GTAW system can be easily met by a rechargable and relatively small battery package. Such versatility would be crucial in repair at locations remote from a power source or during power-down emergency situations on the space station.

However, the significant draw back for GTAW is the requirement for a medium which would transfer the welding arc from the tungsten electrode to the work-piece. Such a medium is supplied on earth by an inert gas (argon or helium or both--also used to prevent the solidifying weld from reacting with oxygen and nitrogen). The inert gas is ionized into a plasma which transfers the welding arc. In space the conventional introduction of an inert gas for plasma formation would prove useless because of the hard vacuum environment. But, a proprietary modification to the terrestrial GTAW process, developed and demonstrated by the Rocketdyne Division of Rockwell International, overcomes the vacuum limitation [2]. Therefore, the fundamental drawback for space based GTAW is eliminated.

In conclusion, the advantages of GTAW outweigh the benefits of its adversary welding techniques; even those of electron beam welding.

What about microgravity effects ?

The environment of space imposes on GTAW an unknown effect due to microgravity. In order to extend the inherent advantages of earth based welding out to space, it is important to compare the properties of a terrestrial welded joint with those of its space counterpart.

Concerning the solidification of a molten weld pool, theory suggests that the absence of gravity eliminates buoyancy driven convection, isothermal buoyancy, sedimentation and metallostatic pressures [3]. For example, the lack of buoyancy driven convection may entrap bubbles formed at the solidification front [3,4]. This would introduce porosity; therefore, increasing the affinity to corrosion and reducing joint strength. On the other hand, the elimination of buoyancy driven convection may also eliminate micro- and macro-segregation thus promoting a more homogeneously solidified material and improving joint characteristics. Weld seam geometry is another interesting example of controversy. One theory suggests that, with the absence of metallostatic forces, surface tension will cause the liquid metal pool to assume a near spherical shape which would minimize surface energy. However, another view point stresses that a liquid medium in microgravity would demonstrate higher affinity towards its solid parent medium than it would in a 1-g environment; resulting in a thinning of the weld pool and solidifying seam [4]. Obviously, experimentation is required to settle these controversies and many others.

Even though the United States, USSR and West Germany have experimented with microgravity welding, no substantial data exists about GTAW [3,5]. In addition, data from the welding techniques already performed in microgravity vary with the processes, joints and materials used -- no definite common trends exist. Some samples show porosity while others don't; some samples reveal larger weld zones while others don't; some samples suggest a more uniform grain structure throughout the heat affected zone while others don't; and some samples show greater reinforcement of welded seams while others don't [3]. Unfortunately, uncertainty exists with the available experimental data relating the effects of microgravity to macro- and microstructural properties of welded joints.

In summary, more factual data about welding in microgravity is needed as a first step in qualifying GTAW as a metal joining process for space based operations. The vacuum of space can be simulated very closely on earth; and indeed Rockwell International has already demonstrated a method for vacuum GTAW. But, microgravity is harder to come by. Hence, the Rockwell International / Cal Poly Space Systems' G-169 is meant to reveal the effects of microgravity on the properties of the solidified Gas Tungsten Arc (GTA) welded joint.

G-169

Objective :

The objective of G-169 is to allow comparison of a space GTA welded joint to a terrestrial GTA welded joint with all welding parameters held constant except for gravitational forces. Upon retrieval of G-169 from its mission, the space welded specimen will be compared to its terrestrial counterpart via metallographic examinations such as macro- and microphotography, microhardness, tensile, radiography, and scanning electron microscopy.

The most likely and preliminary candidate for space based GTAW application would be the Space Station's power system (contracted to Rockwell International's Rocketdyne Division) [5]. Rocketdyne's Space Station power system design includes a considerable amount of stainless steel plumbing for flowing heat transfer fluids. At present, mechanical connectors which are unavoidably bulky, heavy and expensive are used at the plumbing joints. On the other hand, the use of GTA welded joints, which exhibit superb low profile beads, would be ideal for plumbing. Hence, in order to maintain a direct application for the specimen to be welded, a bead-on-plate-weld around the perimeter of a 2.00 inch diameter Stainless Steel 316-L pipe section will be performed; to simulate a butt-joint (an actual butt-joint would require two adjacent pieces of pipe which may vibrate and separate during shuttle launch).

Concept : (see figure)

The basic components of G-169 consist of a controller, battery-pack, power inverter, welding computer, welding head, and an inert gas pressure vessel. The controller manipulates and safeguards operations of the payload components. The rechargable battery-pack supplies power to the entire payload via the controller. The power inverter converts the DC power-output of the battery-pack to a compatible AC power-input for the welder's operation.

I

The welding computer regulates power to, and operations of the welding head and inert gas purge. The welding head, housing a rotating tungsten electrode, welds along the outside perimeter of the pipe specimen. And last, the inert gas pressure vessel floods the welding area with argon in order to imitate the gas's presence in earth like GTAW. Prior to launch, the G-169 payload is purged in a GAS canister with dry nitrogen gas at one atmosphere of pressure simulating the terrestrial environment (oxygen is eliminated to safeguard against a fire hazard).

Operational Scenario :

The sequence of operations on G-169 is regulated by a cooperation of the controller and the welding computer. Placing switch (A) of the Astronaut Payload Controller (APC) in the "HOT" position initiates start-up of G-169's (internal) controller. The controller initiates a 30 minute time delay to permit cessation of astronaut activity (into a sleep period); in order to achieve as low induced accelerations as possible on the orbiter. Following the delay, power is applied to the welding computer through the power inverter. The computer initiates an additional 7 minute time delay to permit some of its sensitive circuitry to warm up to a safe operating temperature. Following this second time delay welding is performed. The welding procedure involves 30 and 20 second periods of argon gas-flooding of the weld zone, prior and after (respectively) actual welding takes place. The actual welding (arc transfer) takes approximately 2 minutes, during which argon gas-flooding continues and the tungsten electrode rotates around the stationary pipe specimen in a programmed manner. Upon completion of the welding procedure the welding computer signals the controller to cut-off all payload power immediately. The duration for the entire experiment, including time delays, is 45 minutes.

Spin-Offs for GAS Users :

Following the Challenger tragedy and the consequent halt of Space Shuttle flights, Rockwell International convinced NASA to provide other means of microgravity simulation for G-169.

NASA Lewis Research Center, specializing in microgravity research, is sponsoring G-169 with at least four free flights aboard a special Learjet aircraft. A microgravity environment, varying from 0.001 to 0.01 g's, is attainable for approximately 20 seconds by flying the aircraft through a Keplerian trajectory. The maneuver is entered from a slight dive requiring a 2- to 2.5-g pullup just prior to nulling the accelerations in the three primary axes and it is terminated with a similar pullup to level flight attitude. During the maneuver all personnel, including civilian experimenters, are constrained in seats. In order to attain minimal induced accelerations a maximum of six trajectories can be flown before landing and relubrication of aircraft controls.

In conjunction with G-169, NASA Lewis has acquired a GAS-can and developed an interface between the canister and the jet. Even though a Learjet microgravity simulation does not provide ideal experimental conditions for G-169 (only 20 seconds of microgravity), it will allow an interesting spectrum of gravitational forces between 0.001- and 2.5-g loads, a variety of specimens, and a check of payload performance.

G-169   will set the path for other GAS experiments to be flown aboard the Learjet.
In contrast with the Space Shuttle, Learjet-benefits for the GAS user may include reduced flight
cost, lowered safety requirements, personal experiment operation and the ability to correct
minor experimental failures if they should arise. In addition, Learjet flights may reduce the
backlog of shuttle GAS payloads and expedite return of experimental results.

OTHER DEVELOPMENTS AND FUTURE PROSPECTS

In response to NASA's 1987 competition for Out-Reach in Space Technology (ORST) grants,
a joint entry was submitted by Rockwell's Rocketdyne Division and Cal Poly's Aero Department.
The entry was a proposal for the definition and design of a space flight experiment to evaluate the
feasibility of performing manual welding tasks in an EVA environment. Rockwell and Cal Poly
used their work on G-169 and vacuum GTAW to establish a leading edge for their entry. The
ORST competition, requiring the cooperation of industry and university, awarded over
$120,000 to the Rockwell-Cal Poly proposal for a 12 month design contract. Upon completion
of the EVA welding experiment design, Rockwell and Cal Poly plan to reenter the ORST
competition and submit a follow-on proposal for a substantial grant to develop the experiment
for actual shuttle flight.

UNIVERSITY-INDUSTRY-GOVERNMENT TRIANGLE

Get Away Special Payload #169, is a manifestation of a working relationship between the
academic institution, the aerospace industry, and the government; where all partners cooperate
and benefit in their own ways.

In 1983 a group of engineering students, attending the California Polytechnic State
University (Cal Poly) in San Luis Obispo, decided to weld in space. The only realistic path, both
economically and technically, was through NASA's unique Get Away Special program. After
almost two years of futile soliciting for donations and equipment, the student group established
contact with a generous aerospace company which saw potential in the "space welding" dream.
The company was the Science Center of Rockwell International Corporation. Rockwell agreed to
finance a five cubic foot GAS canister and all related project expenses; including some student
travel to the annual Get Away Special Symposium. Rockwell also extended their resources,
expertise and a project manager. The payload manager was appointed from the Cal Poly student
group and the project advisor was appointed from the university's faculty. The student group
was responsible for the design, purchase, fabrication, integration and testing of components for
the G-169 payload as well as interfacing the project with NASA. Semiannual progress reviews
and regular communication were maintained between the students and staff (engineers,
scientists, etc.) from Rockwell International and NASA. An ideal cooperative working
relationship was established between university, industry, and government.

University students apply and sharpen skills and knowledge which they acquire in the class
room and laboratory; at the same time, they learn a whole new "ball-game" -- the development
of a space rated system from technical and bureaucratic perspectives. Industry's "citizenship"
reputation improves with their financial and technical involvement. And with the addition of

governmental IR&D support a small student side project slowly, but surely, opens doors into serious aerospace applications and potential contracts. Finally, NASA acquires fame for its successful GAS program, and possibly new tools for space exploration.

CONCLUSION

Cal Poly's motto is LEARN BY DOING, and the Get Away Special Program makes it possible by completing the university-industry-government triangle. Both the economical and technical feasibility of a GAS payload allow an aerospace company (like Rockwell International) to extend the helping hand which a student run, learn-by-doing, space project needs. A student group needs a trusting, patient and generous hand which can pull strings and show the way when needed. The Get Away Special Team at NASA Goddard also supplies educational safety reviews and fascinating symposiums as well as granting students the experience and honor of presenting a technical paper to the prestigious aerospace community.

The Get Away Special is a credit to our nation. Programs such as GAS make America special. On behalf of the aerospace students in the United States, I salute the GAS TEAM. Thank you.

ACKNOWLEDGEMENT

REFERENCES

[1]   Eagar, T.W., Professor, Materials Processing Center, Cambridge, MA, MIT, "Prospectus for Development of a Rational Welding Technology for Fabrication in Space", presented to Rockwell International's Rocketdyne Division, 1987.

[2]   Gordon, S., "Development of GTAW Welding Process for Welding in a Vacuum", Internal Rockwell International Rocketdyne Division Report, 1987.

[3]   Hoffmeister, H. and Rudiger, J., Laboratorium fur Werkstoffkunde und Schweibtechnik der Hochschule der Bundeswehr Hamburg, "An Investigation of the Current State of Research into the Influence of Gravity on the Joining of Metals by Means of Liquid Phases", 1981.

[4]   Blake, A. W., former G-169 Payload Manager "Gas Tungsten Arc Welding in a Microgravity Environment Work Done on GAS Payload G-169", 1986 Get Away Special Experiments Symposium, NASA Conference Publication 2438.

[5]   Muir, A. H. Jr., "Materials Processing in Space -- Welding in Microgravity", Internal Rockwell International Science Center Report, 1986.

CONCEPT OF G-169

TOP PLATE

BATTERY PACK

SHELF-A

WELDING HEAD

PRESSURE VESSEL

CONTROLLER

POWER INVERTER

SHELF-B

WELDING COMPUTER

SHELF-C

GCD

APC (A) (B) (C)

POWER   CONTROL   ARGON
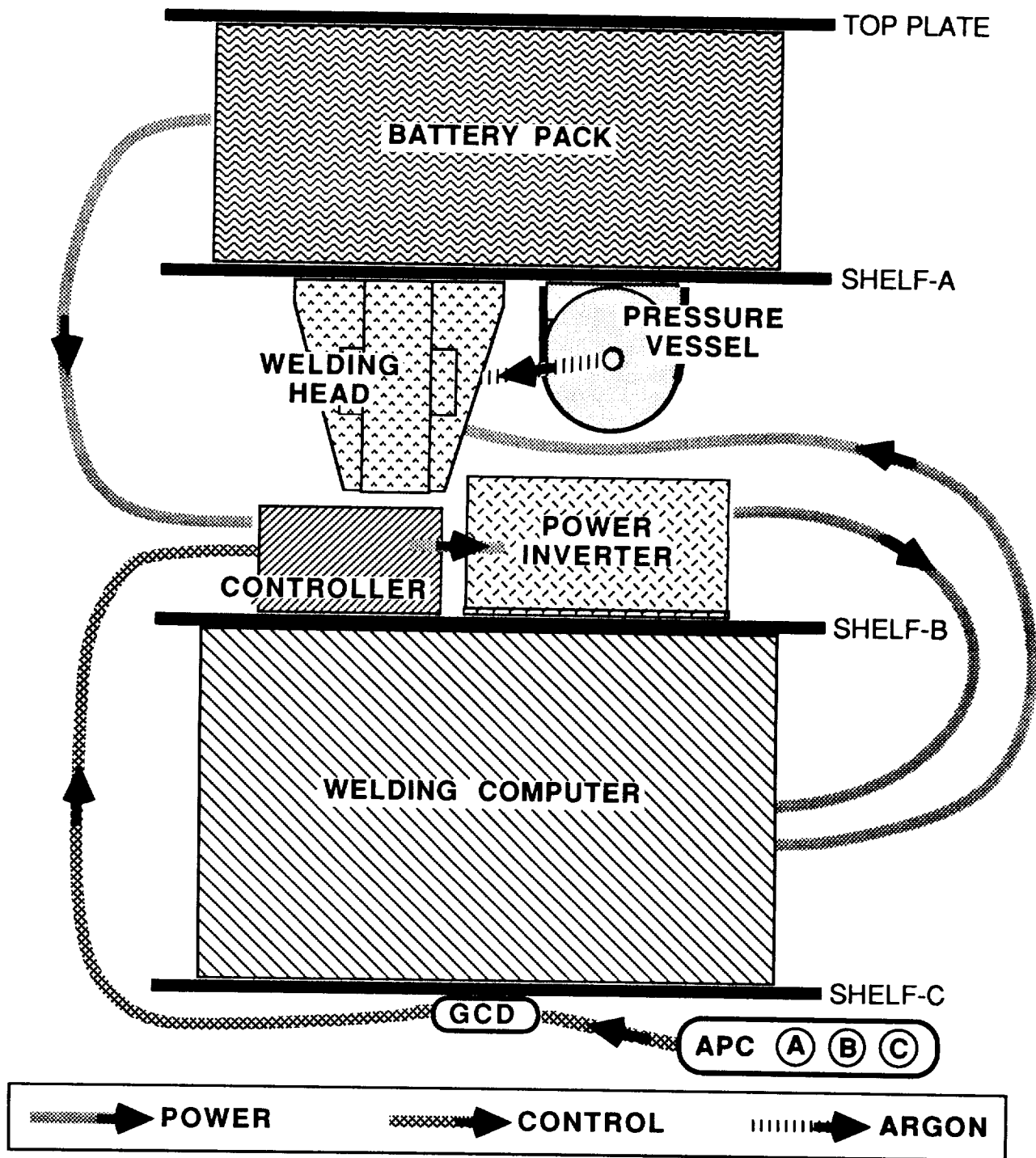
HITCHHIKER CAPABILITIES

Theodore C. Goldsmith

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

June, 1988

OVERVIEW:

A new carrier system has been developed for economical and quick response flight of small attached payloads on the Space Shuttle. Hitchhiker can accommodate up to 750 lb. of customer payloads in canisters or mounted to an exposed side-mount plate or up to 1200 lb. mounted on a cross-bay structure. The carrier connects to the orbiter's electrical systems and provides up to six customers with standard electrical services including power, real time telemetry, and commands. A "transparent" data and command system concept is employed to allow the customer to easily use his own ground support equipment and personnel to control his payload during integration and flight operations. The first Hitchhiker was successfully flown in January 1986 on STS 61C.

Hitchhiker is an extension of the Space Transportation System (STS) capabilities, is operated by the NASA Office of Space Flight Carrier Systems Division, and is available to any STS customer. The Hitchhiker approach has been specifically designed to be user friendly, reduce the time and effort required of space flight customers, and make most efficient use of STS payload capacity.

HITCHHIKER PROGRAM

The Hitchhiker Program was initiated in early 1984 by the NASA Office of Space Flight with the objectives of providing a quick reaction and low cost capability for flying small payloads that required more services than Get Away Special (GAS) experiments but did not require the extensive, custom, services of a Spacelab. The Hitchhikers will be flown under the NASA STS secondary payload program. Two versions of Hitchhiker were selected: Hitchhiker-G, developed by Goddard Space Flight Center (GSFC), can carry up to six customer payloads weighing a total of up to 750 lbs. mounted on the side of the payload bay; Hitchhiker-M, developed by Marshall Space Flight Center (MSFC), was combined with the GSFC Project at Goddard in 1987. HH-M will have electrical interfaces and services identical to HH-G and will carry up to 1200 lb. of customer equipment mounted on a cross-bay bridge type structure.

Hitchhiker payloads may be accommodated in the Shuttle under either the STS Small Payload Accommodations (SPA) policy or under the Standard Mixed Cargo (SMC) policy. The SPA policy has restrictions regarding crew activity, power, harness arrangement, payload bay location, etc. intended to simplify Shuttle integration and analysis and so has shorter lead time requirements and increased manifesting flexibility. Payloads on Hitchhiker carriers flying under the SMC policy may use almost any STS interface, resource, or activity available to any other STS secondary payload at the expense of increased lead time and reduced manifesting flexibility. Hitchhiker payloads are manifested and processed under a name and acronym assigned by the customer.

Hitchhikers are nominally carried in "bays" 2 and 3 near the forward end of the payload bay. Hitchhiker-G is side mounted on the starboard side to avoid interference from the RMS which is normally carried on the port side. In order to meet the requirement for quick reaction Hitchhiker is designed with standard pre-defined electrical interfaces and also has special transparent data system features to reduce the time required to perform electrical integration and checkout of the customer hardware on the carrier. Mechanical interfaces are also simple and consist of a flat vertical plate with a 70 mm. grid hole pattern or a canister similar to GAS with or without a motorized door on HH-G and standard mounting rails on HH-M.

Hitchhikers are considered secondary payloads and may not interfere with primary payload requirements on the same mission. Unique crew activity and attitude (pointing) requirements of a limited nature (Eg. several hours) can usually be accommodated on a SPA payload. Allowable activities on SMC payloads are negotiable.

SHUTTLE PAYLOAD OF OPPORTUNITY CARRIER (SPOC)

The Hitchhiker-G was implemented using the Shuttle Payload of Opportunity Carrier (SPOC). The SPOC system is designed to be modular and expandable in accordance with payload requirements to allow maximum efficiency in utilizing orbiter resources and thereby increase the potential for early manifesting on the Shuttle. A typical Hitchhiker-G configuration is shown in Figure 1.

FIGURE 1

HITCHHIKER-G2 (ASP/PMG) CONFIGURATION

MDA CANISTER
WITH PMG

ASP

HH AVIONICS

GAS BEAM

SMALL
MOUNTING PLATE

BAY 2

BAY 3
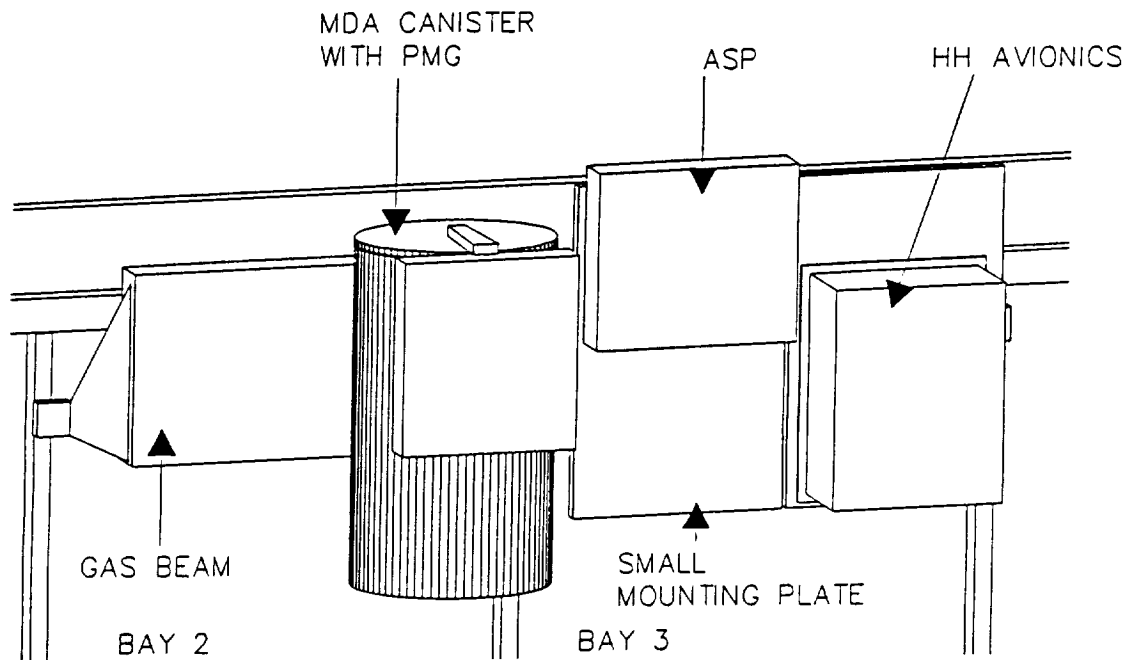
HITCHHIKER-G MISSION ONE

PERKIN-ELMER SHUTTLE ENVIRONMENTAL
EFFECT ON COATED MIRROR (SEECM)
INSTRUMENT

USAF PARTICLE ANALYSIS
CAMERAS FOR SHUTTLE
(PACS) INSTRUMENT

GSFC
CAPILLARY PUMPED LOOP
(CPL) INSTRUMENT

AVIONICS PACKAGE

99
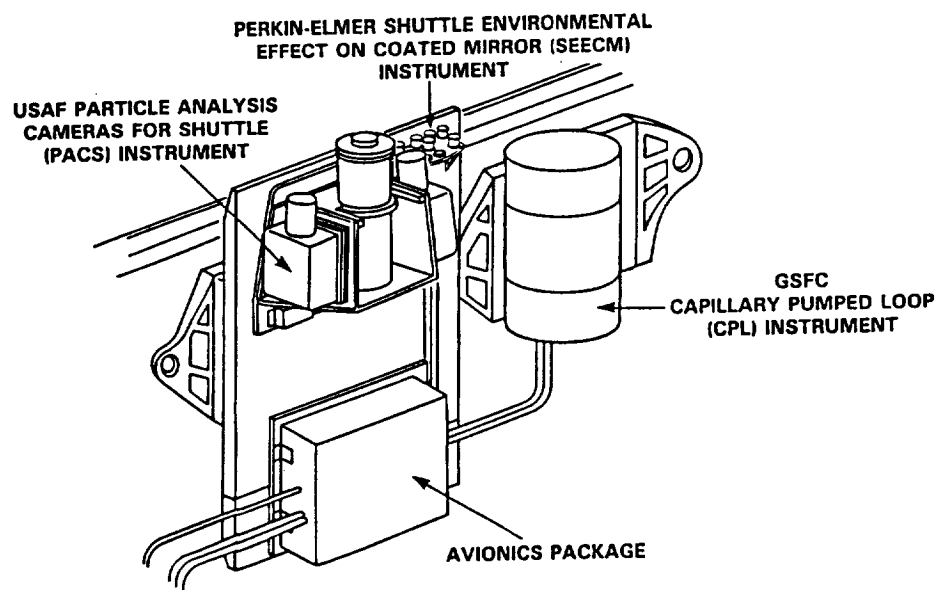
The SPOC system consists of the following elements:

The avionics unit provides standard electrical interfaces for up to six customer payloads. It contains a microprocessor control unit, relay switching equipment, medium-rate multiplexer, and other hardware necessary to interface with the customer hardware and orbiter. A switch panel in the cabin allows the crew to activate and de-activate the payload and provides an independent command path to control inhibits to any hazardous functions. Under SMC policy a crew keyboard/display unit may also be used.

The SPOC plate provides a 50 by 60 inch mounting surface for the avionics and customer hardware. The plate accepts 3/8 inch bolts on 70 mm. centers and is equipped with heaters, thermostats and thermistors for maintaining and measuring thermal control of the plate and mounted hardware as well as thermal blankets and surfaces for the back and unused portions of the front of the plate. Plate mounted customer hardware may need additional customer provided blankets, heaters, or other thermal control provisions. A smaller and lighter 25 by 39 inch plate may also be used to mount customer hardware or to mount the avionics unit. All Hitchhiker-G equipment attaches to the orbiter longeron and frame structure via three large bolts and the "GAS beam" attachment fitting. In unusual cases customer hardware may be attached directly to the attachment beam.

The SPOC motorized door canister has mechanical interfaces nearly identical to a GAS canister and can accommodate a customer payload of up to 170 lbs., 19.75 inches in diameter and 28 inches deep. A sealed canister (no door) can also be chosen and can accommodate 200 lbs. of payload in an atmosphere of nitrogen or air. The canisters may be insulated or uninsulated depending on the customer's heat rejection requirements. An uninsulated canister can reject several hundred watts of heat (steady state) under typical conditions and is normally used where the customer requires high power dissipation. Even higher dissipation is possible over short periods (hours) separated by cool-down intervals. The customer's payload must contain heaters and thermostats to maintain the desired temperature.

The standard electrical interface or "port" consists of a signal cable and a separate power cable which provide the following:

o Two 28 V (+/- 4 V) 10 Amp. power lines which can be turned on (together) by ground command. Customer power and energy are monitored by the carrier system. The maximum simultaneous total customer power for a Hitchhiker is 1300 W and the nominal maximum total customer energy is about 4 Kwh/ day with additional energy negotiable (SPA policy). Under SMC policy customer power and energy are 1600 W and about 10 Kwh/day.

o Four 28V bi-level or pulse commands (10 ma max) which can be used with relay drivers and relays to control additional power switching within a payload. (For canister payloads one command is reserved for control of the door.)

o An asynchronous 1200 baud uplink command channel.

o An asynchronous 1200 baud low-rate downlink data channel. This data is available over Ku-band service or S-band service and can also be recorded on the orbiter's tape recorder.

o A medium-rate downlink channel 1-1400 KB/s for use with the real-time-only Ku-band TDRS service. The total simultaneous customer data rate for the Hitchhiker cannot exceed 1400 KB/s.

o IRIG-B serial time code and a one pulse per minute square wave signal which can be complemented by a time command via the above asynchronous uplink channel.

o Three channels for temperature sensors to allow measurement of payload temperatures even when the payload power is off (for canister payloads these channels are reserved for door position, canister pressure, and temperature).

o An analog channel, 0-5V, 8 bit quantizing, 10 hertz sample rate. An index pulse is also supplied which can be used to advance a user supplied analog multiplexer to allow measuring a large number of parameters.

In order to provide low cost, quick reaction, and increased autonomy for the customer, SPOC has been implemented with a transparent data system concept (fig. 3). The Customer provided Ground Support Equipment (CGSE), associated software, and personnel can be used to generate commands to the customer's payload and display data from the payload during payload to carrier integration and verification testing and also during flight operations. The asynchronous data and command interfaces, and medium-rate data interface are transparent in that the interface between the customer's flight hardware and the carrier is identical in electrical characteristics and protocols to the corresponding interface between the SPOC GSE and the CGSE thus the GSE the customer used during development of his instrument may be used without modification during carrier integration and flight. The remaining interfaces (bi-level commands, analog channel, etc.) can also be connected but require conversion to asynchronous format at the CGSE. If desired the CGSE can also be provided with orbiter attitude and position data. These interfaces operate in real-time with transmission delays of 5-15 seconds during flight. Simpler experiments with minimal command and data display requirements can be accommodated without customer delivered GSE. All of the data is available on computer compatible (9 track) magnetic tape within one month after the flight.

The Hitchhiker-M carrier has mounting rails for customer hardware in three places on each side (27.9 x 28.2 inches) and three positions (36.0 x 28.2 inches) on the top.

HITCHHIKER MANIFESTING SCENARIO

Prospective Hitchhiker customers first discuss their requirements with the Goddard Project Office to determine feasibility and compatibility with Hitchhiker capabilities. They then submit a Customer Payload Requirements (CPR) document to GSFC and a Request for Flight (NASA form 1628) through the appropriate NASA Headquarters discipline office. Under the NASA STS secondary payload policy adopted in 1987 each discipline office has been assigned a percentage of the available secondary payload weight available on the Shuttle (Virtually all payloads under 8000 lb. are considered

secondary payloads). Each office prepares a list of its secondary payloads in priority order. In the case of Hitchhiker payloads the "chargeable weight" of the payload will include the weight of the necessary carrier equipment. The STS manifesting office creates the manifest using an algorithm and the discipline priority lists. There are two separate reimbursable categories under which foreign and domestic customers can purchase space on Hitchhiker. Costs for this service are not firm but are expected to be the same as the standard mixed cargo pricing (currently about $2100/lb.) for customer and carrier equipment plus an integration charge. At present about 112,000 lb. of space has been identified for manifested secondary payloads through 1993. Approximately an additional 75,000 lb. of capacity is being held as contingency reserve. This contingency (if not required by the primary payloads) is released to use by secondary payloads and Get-Away-Special at specified intervals before the flight. Because short lead times are involved in using the contingency space it will be applied mainly to Get-Away-Specials and secondary payloads meeting the SPA policy.

As of May, 1988, the secondary payload discipline offices, and their allocation of secondary payload space (percent) are as follows:

Discipline	Percent
Science and Applications (E)	38
Commercialization (C)	31
Space Station (S)	10
Space Technology (R)	9
STS Technology (M)	5
Administrator (A)	3
Foreign Reimbursable (X)	3
Domestic Reimbursable (C)	1
DoD (under review)	0
Total	100

Since secondary payloads are manifested in space remaining after accommodation of the primary payloads, manifesting opportunities are extremely sensitive to payload weight. The weight of each payload (including carrier) is subtracted from the discipline office allocation as the payload is manifested. Approximate weights of various Hitchhiker carrier items (lbs.) are as follows:

Gas Beam attach fitting	170
50 x 60 inch plate	370
25 x 39 inch plate	55
Avionics unit	155
Motorized door canister	235
Sealed canister	160
Hitchhiker-M carrier (including avionics)	1800
HH-M attach fittings	400

At least 24 months (SMC payload) or 13 months (SPA payload) before flight the

Fig. 2 SPOC PLATE

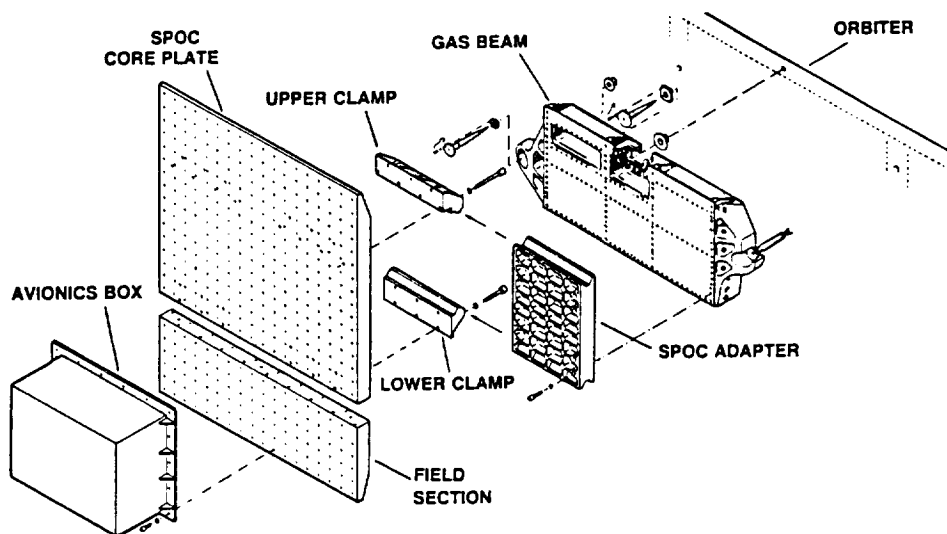AT CUSTOMER'S FACILITY

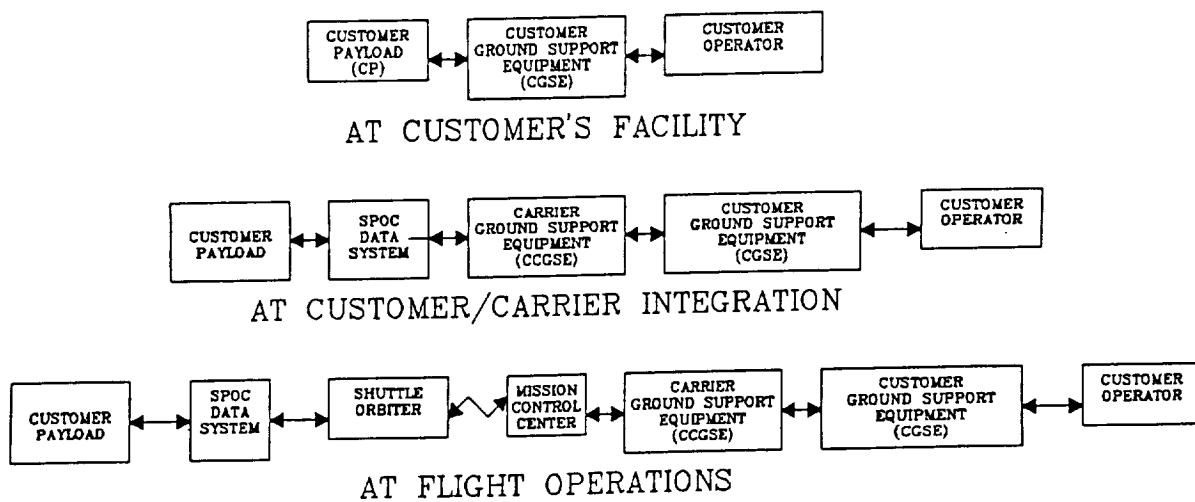AT CUSTOMER/CARRIER INTEGRATION

AT FLIGHT OPERATIONS

Fig. 3 SPOC TRANSPARENT DATA SYSTEM COMMUNICATIONS

103

customer delivers complete documentation on his payload to GSFC. The safety data package requirements are similar to GAS in the case of canister payloads but are somewhat more complex if the customer's equipment will be plate mounted. About 6 months before flight the customer's hardware is delivered to GSFC and with the help of the customer and his CGSE the payload is integrated to the carrier, and system functional tests and EMI tests are performed. Prior to delivery the customer is responsible for performing any necessary tests required for safety certification (such as static load tests) as well as any tests required by the customer to confirm proper operation (such as vacuum or vibration tests). Following tests at GSFC the integrated payload is shipped to Kennedy Space Center and integrated into the orbiter where only interface verification tests are performed. Launch occurs typically about 8 weeks after orbiter integration. During flight the Hitchhiker is operated from a control center at GSFC with participation of the customers and their CGSE. Displays of orbit position, attitude, ancillary data, and any downlink TV are provided along with access to crew voice transmissions. Following landing the Hitchhiker is removed and de-integrated and the customer hardware is returned to the customer at KSC or GSFC.

HITCHHIKER MISSIONS

The Hitchhiker-G1 payload (fig. 4) flew on STS 61C in January 1986. The customer payloads were: The USAF Particle Analysis Cameras for Shuttle (PACS) which was designed to make photographs of particle contamination in the vicinity of the orbiter; The NASA/GSFC Capillary Pump Loop (CPL) experiment which determined the zero-gravity performance of a proposed Space Station thermal system; and the NASA/Perkin Elmer Shuttle Environmental Effects on Coated Mirrors (SEECM) experiment which studied the effects of residual atmosphere on telescope mirror contamination. The PACS consisted of a stereo camera and flash assembly mounted on the upper portion of the plate. The CPL instrument was carried in a sealed canister and was connected to multiple power ports to allow over 1000 W of power to be used. The carrier operated nominally with over 800 commands being sent and over 120 hours of data obtained. Currently, six Hitchhiker-G and four Hitchhiker-M missions are manifested.

FUTURE ENHANCEMENTS UNDER STUDY

The following are enhancements which may be added to the SPOC system in the future depending on demand and feasibility:

o An ejection mechanism to allow deployment of small probes or spacecraft from the canister. This would be similar to the existing GAS system except that power and electrical services could be obtained prior to launch via an umbilical connector. Spin-up capability is also being studied. Payloads up to 150 lbs. could be accommodated.

o Capability for attaching Hitchhiker-G type accommodations (canisters, plates) to the Hitchhiker-M carrier.

o A method for late installation of payloads into motorized door canisters on the launch pad to reduce the time-to-launch from 8 weeks to 2-3 days.

o A cooling system to extend the existing heat rejection capability.

o A larger canister.

o A longer canister.

o A probe bus for ejectable experiments is being considered. This bus would be ejected from a canister, contain batteries, data system, transmitter, and receiver and would carry a customer's instruments for a brief mission in the vicinity of the orbiter while communicating to an antenna and SPOC port on the attached carrier.

FURTHER INFORMATION

For further information about the Hitchhiker Program contact:

Hitchhiker Project Office
Goddard Space Flight Center Code 740
Greenbelt,Md. 20771

ATTN: T. Goldsmith (301) 286-8799
or C. Prouty (301) 286-9090

Hitchhiker Program Office
NASA Headquarters Code MK
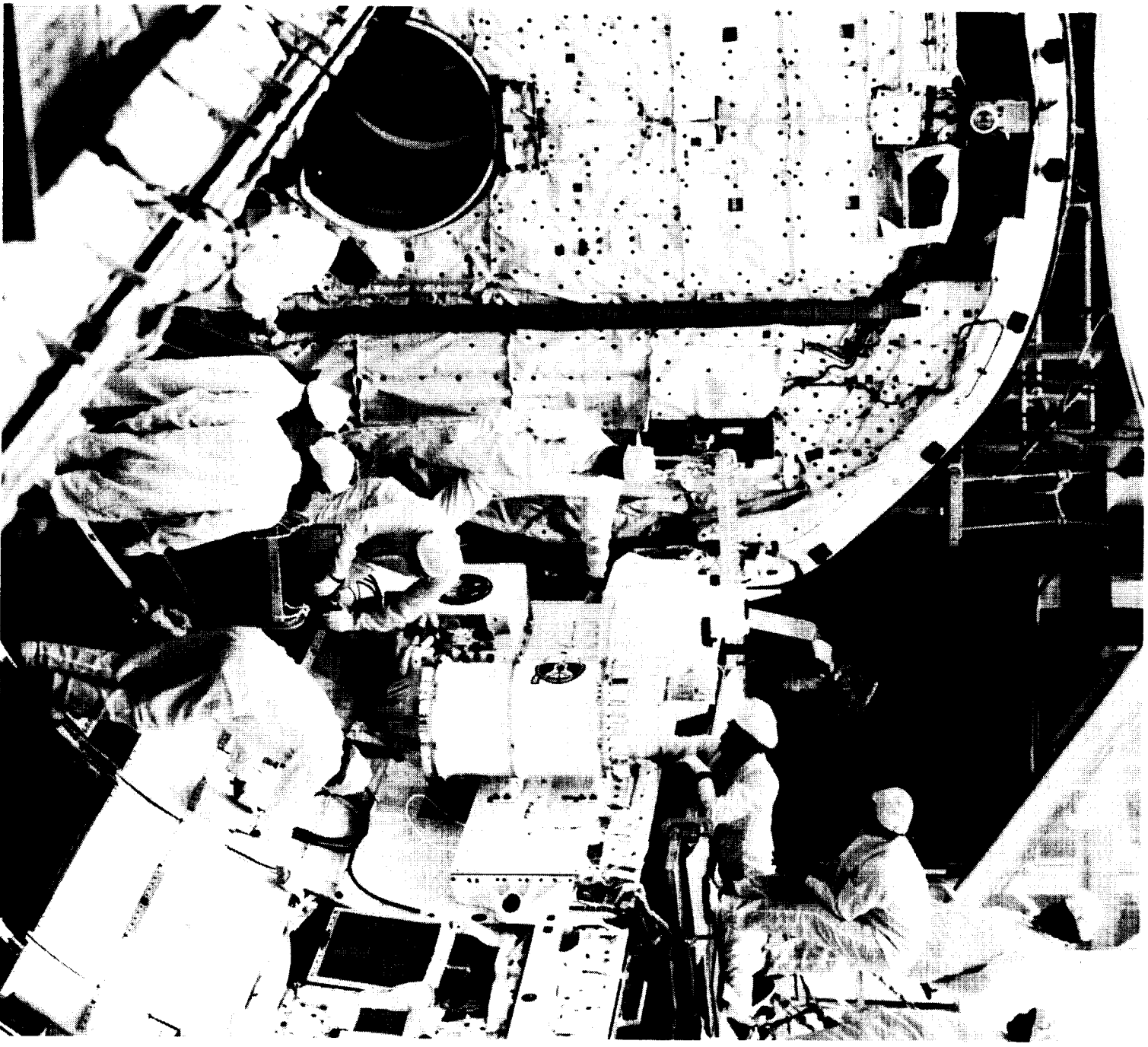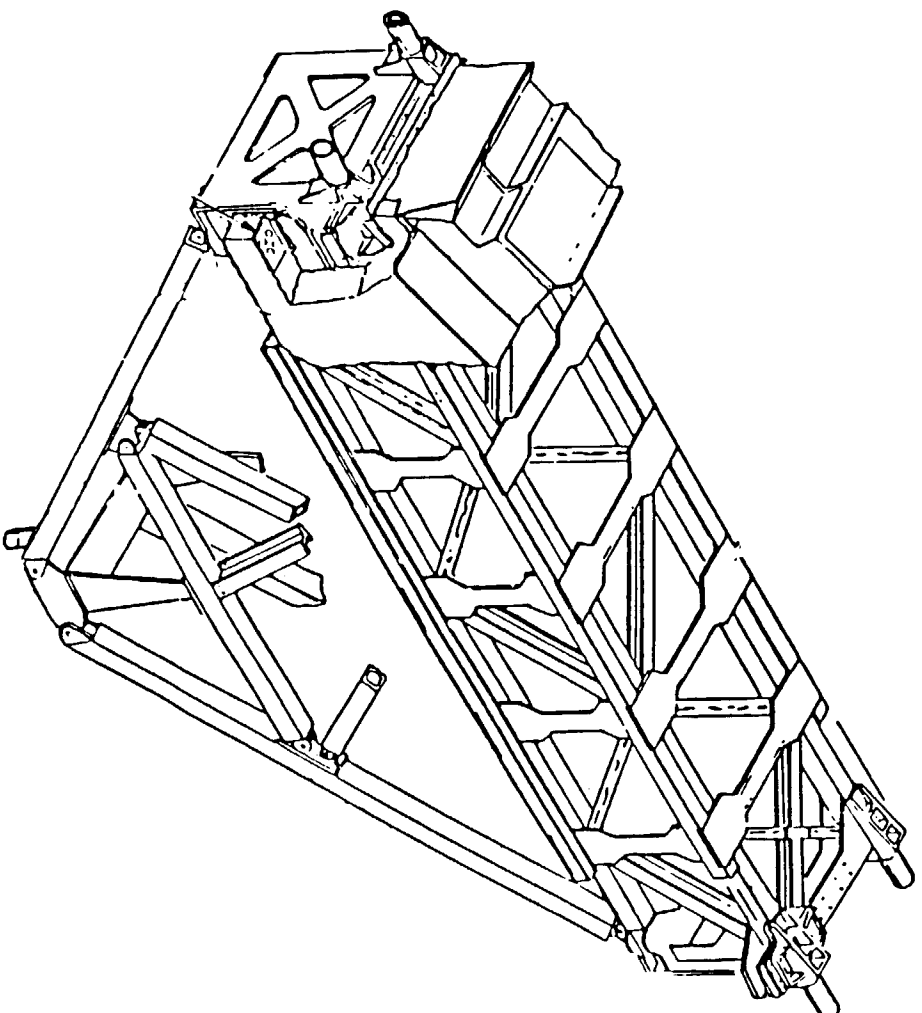Washington, D.C. 20546

ATTN: E. James (202) 453-1899

FIG. 4 HITCHHIKER-G1 PAYLOAD INSTALLED IN ORBITER COLUMBIA

HITCHHIKER-M CARRIER

The Purdue University Get Away Special II
(PUGAS II)

Christopher Olenski, Alan R. Crocker, Beth Stubbings,
Laurie McCormick, and Paul K. Andersen

Purdue University
West Lafayette, Indiana 47907

Abstract

The Purdue University Get Away Special Project is a student-run organization dedicated to preparing payloads for flight on NASA's space shuttle. The first such payload (PUGAS I) flew on Challenger in 1983. The second payload (PUGAS II) should be ready by the end of this year. Three experiments will be included. The first experiment will involve the production of tin metal foam under microgravity conditions. The second experiment will focus on the desorption of water from carbon-epoxy composite materials. The third experiment will use a solid polymeric material to detect radiation in space.

Introduction

This project was made possible through the continuing Small Self Contained Payload (SSCP) program of the National Aeronautics and Space Administration (NASA). The intent of this program is to generate new activities unique to space by providing numerous, frequent opportunities for small industrial users and educational institutions to fly payloads on the shuttle. Because of its low cost, the SSCP program is commonly referred to as the "Get Away Special " or GAS program. NASA hopes that this program will encourage greater use of the shuttle for education, commerce and research.

History of PUGAS I

The Purdue University Get Away Special (PUGAS) project began in 1978. A Purdue alumnus, Dr. Harold W. Ritchey, donated an SSCP reservation to provide students "hands-on" design experience. The students were expected to manage the project themselves, from the initial concepts through to the post-flight analysis of the collected data.

Three experiments were developed for the first payload. The Geotropism Experiment was designed to investigate the effects of gravity on the germination and initial growth of sunflower seeds. "Geotropism" refers to the process by which sprouts orient themselves in a gravitational field. A centrifuge is commonly used to study this effect; the centrifugal force acts as an additional body force on the sprout. However, gravity on the at the earth's surface introduces a bias that complicates interpretation of experimental results—hence the interest in working under microgravity conditions. In this experiment, 200 sunflower seeds were distributed at various radii in a centrifuge wheel, where they would be subjected to different levels of acceleration. Once in orbit, the seeds were to be sprayed with water, thus initiating germination; after 72 hours, the sprouts were to be sprayed with a fixer/preservative (glutaraldehyde).

The Zero-Gravity Fluid Dynamics experiment was designed to investigate the motion of a fluid in a microgravity environment. A drop of mercury was placed in a cell containing approximately 10 cubic centimeters of a perfluorinated hydrocarbon liquid. A motion picture camera was aimed through a window in the cell to record the response of the mercury drop to shuttle maneuvers.

The Nuclear Particle Detector was designed to record the passage of nuclear particles (such as cosmic rays) through the GAS canister. The detector comprised 75 thin sheets of a sensitive polycarbonate plastic, stacked together in an aluminum box. When an energetic charged particle passes through the polycarbonate, it disrupts the polymer structure along its path. This makes the polymer locally more susceptible to chemical attack. A caustic solution will etch a pit in the polycarbonate, thereby marking the track of the particle.

The PUGAS I payload took some four years to develop, at a cost of about $25,000. Nearly a hundred students, almost all of them undergraduates, worked on the project at various times over that period. The payload flew aboard STS-7 (Orbiter Challenger) 18-24 June 1983. Unfortunately, the geotropism and

fluid experiments failed to operate because of a short in the power system. In contrast, the nuclear particle detector was a complete success; a detailed report was published by Weber and Weber (1984). Additional information on the PUGAS I project can be found in the paper by Perez (1984).

PUGAS II

The current space shuttle project, known as PUGAS II, began in 1984. Reservations were made for a 2.5-cubic-foot GAS cannister having a 100-pound capacity. Two dozen students are involved in PUGAS II. The work is divided among five engineering design groups (Microprocessor Control, Structures, Power, Thermal Control, and Safety) and three experimental groups (Materials Processing, Nuclear Particle Detection, and Moisture Desorption).

This paper will concentrate on the work of the experimental groups. The PUGAS II microcontroller was previously described by Weber and Deckard (1986). The construction of the lightweight composite structure was described by Spencer (1986). The thermal control system for PUGAS II will be similar to that used for PUGAS I, which was described by Stark (1985).

Materials Processing

This experiment is designed to investigate the feasibilty of producing foamed-metal materials in space. A foamed metal is one in which a significant fraction of the material's volume is occupied by gas bubbles. Such materials are light and strong, and may prove useful for constructing structures in space. On earth, foamed metals can be produced by bubbling gas through a molten metal, but buoyancy and convection tend to distribute the gas bubbles unevenly. It is hoped that a uniform distribution of bubbles might be achieved under microgravity conditions in orbit.

In the Purdue experiment, a small quantity of zinc carbonate is mixed with powdered tin. This mixture is pressed to form cylindrical rod, approximately 2.5 cm in diameter and 2.5 cm long, which is placed inside a stainless steel cylinder. The end of steel cylinder is then closed by the insertion of a movable piston. Nichrome heating elements are wrapped around the cylinder, and the entire assembly is placed in an insulated steel containment vessel in the GAS canister.

Once in orbit, the microcontroller will activate the experiment by supplying battery power to the heating elements, raising the temperature of the sample to about 600 K. Tin melts at 505 K; zinc carbonate decomposes into zinc oxide and carbon dioxide above 575 K. Thus, bubbles of carbon dioxide gas will form throughout the molten tin, causing the sample to expand against the piston. On command from the microcontroller, the power to the heating elements will be cut, and the sample will be allowed to cool. As the tin solidifies, it will trap the carbon dioxide bubbles.

After the flight, the sample will be removed from the cylinder and subjected to various mechanical tests (for hardness, tensile strength, etc.) The material will then be sectioned and examined by electron microscopy.

Moisture Desorption

In this experiment, carbon-epoxy materials will be exposed to the vacuum of space to determine what changes in tensile strength may result from the loss of volatile substances such as water. Because of their impressive strength and low density, carbon-epoxy materials are finding widespread use in aerospace applications. Obviously, anything that changes the physical properties of these composites will be of interest to the designer.

The experiment itself is fairly straightforward. Samples of the carbon-epoxy composite will be fabricated at the Purdue Department of Aeronautical and Astronautical Engineering. These will be weighed and placed inside a gastight aluminum chamber in the GAS canister. In orbit, a valve on the chamber will be opened, and will remain open until just before the shuttle is to return to earth. The valve will then be closed, sealing the chamber under vacuum. On the ground, the chamber will be transferred to a glove box containing a dry, inert atmosphere. The carbon-epoxy samples will be weighed, then tested to determine their tensile strength.

110

Nuclear Particle Detection

The present particle detector is similar to the detector that flew on PUGAS I. The principle of the experiment remains the same: interactions with energetic charged particles weaken the polymer structure, resulting in the formation of pits when the sample is subsequently exposed to a chemical etchant. The number and energies of the particles can be inferred from an examination of the pits. Colorless allyl diglycol polycarbonate sheets (sold as "CR-39" by Pittsburgh Plate Glass) will be used, as in the original experiment. Forty sheets, 10 cm by 10 cm by 0.32 cm thick, are stacked together between two aluminum end plates. Cutouts in the aluminum allow direct access to the polymer surface. The assembly is secured to the inside of the GAS canister by four bolts.

A second detector is being constructed using red polycarbonate sheets ("LRI-115"). The red material reacts to the charged particles and the caustic etchant in much the same as the colorless material. The difference is that the tracks should be more readily visible in the red material when it is examined under under contrasting green light.

An improved standard was made for the current experiment. Polycarbonate was exposed to a 14.9 MeV proton beam from the Purdue Particle Accelerator, then etched with a sodium hydroxide solution in the usual manner. This provides a reproducible standard with which the exposed polycarbonate sheets from the space shuttle can be compared.

Acknowledgements

References

Perez, R. (1984). Results of the Purdue University GAS-I Payload. *Get Away Experimenter's Symposium* (NASA Conference Publication 2324).

Spencer, M. B. (1986). Use of Lightweight Composites for GAS Payload Structures. *Get Away Experimenter's Symposium* (NASA Conference Publication 2438).

Stark, J. A. (1985). Thermal Control System of the Purdue University Space Shuttle Payload. *Journal of Spacecraft and Rockets*, Volume 22, Number 3, 382-384.

Weber, D. R., and T. W. Deckard (1986). Multipurpose Microcontroller Design for PUGAS II. *Get Away Experimenter's Symposium* (NASA Conference Publication 2438).

Weber, M., and D. R. Weber (1984). Nuclear Particle Detection Using a Track-Recording Solid. *Get Away Experimenter's Symposium* (NASA Conference Publication 2324).

The Transportation of Fine Arts Materials
Aboard the Space Shuttle Columbia

G.A.S. Payload #481

VERTICAL HORIZONS

Ellery Kurtz and Howard Wishnow

ABSTRACT

The Vertical Horizons experiment represents an initial investigation into the transportation of fine arts materials aboard a Space Shuttle. Within the confines of a G.A.S. canister, artist quality fine arts materials were packaged and exposed to the rigors of space flight in an attempt to identify adverse effects.

INTRODUCTION

Currently, little experimentation is being done in assessing the hazards of transporting fine arts materials aboard a Space Shuttle. This initial experiment will provide a foundation upon which additional data may be compiled in order to safely transport objects of visual art into space.

Contained inside our G.A.S. canister (see Figure 1) were samples of linen canvas in three states: raw, primed and painted, which were concentrically rolled in polyurethene foam. On the painted portions of the experimental samples we chose to create actual paintings with a wide variety of pigments rather than patches and painted strips in order to exemplify the type of artistic materials which may be used in future space environments. In the center of the canister we installed a **Tattletale**™ **Thermograph,** furnished by the **Onset Computer Corporation.** This instrument was intended to record temperature changes inside the G.A.S. canister at hourly intervals. Throughout the mission, pressure in the canister was maintained at one atmosphere.

Our intention was to identify any accelerated degradation in the experimental samples caused by the cumulative effects of vibration, temperature change, zero gravity and G-force stress resulting from Space Shuttle flight.

PROCEDURE

The following is a list of materials selected for use in this experiment:
    A. Three 16 x 12 inch samples of unprimed Belgian linen (UP1)
    B. Three 16 x 12 inch samples of single-primed Belgian linen (SP1)
    C. Three 16 x 12 inch samples of double-primed linen (DP1)
    D. Three 19 x 15 inch samples of single-primed Belgian linen painted with oil colors (SPP1)

TOP

Experimental
Samples
(spaced 10" apart)

Thermograph

G.A.S. Canister

Concentric
Layers of
Polyurethane

VERTICAL
CROSS
SECTION

Thermograph

G.A.S. Canister

3" NASA Interface
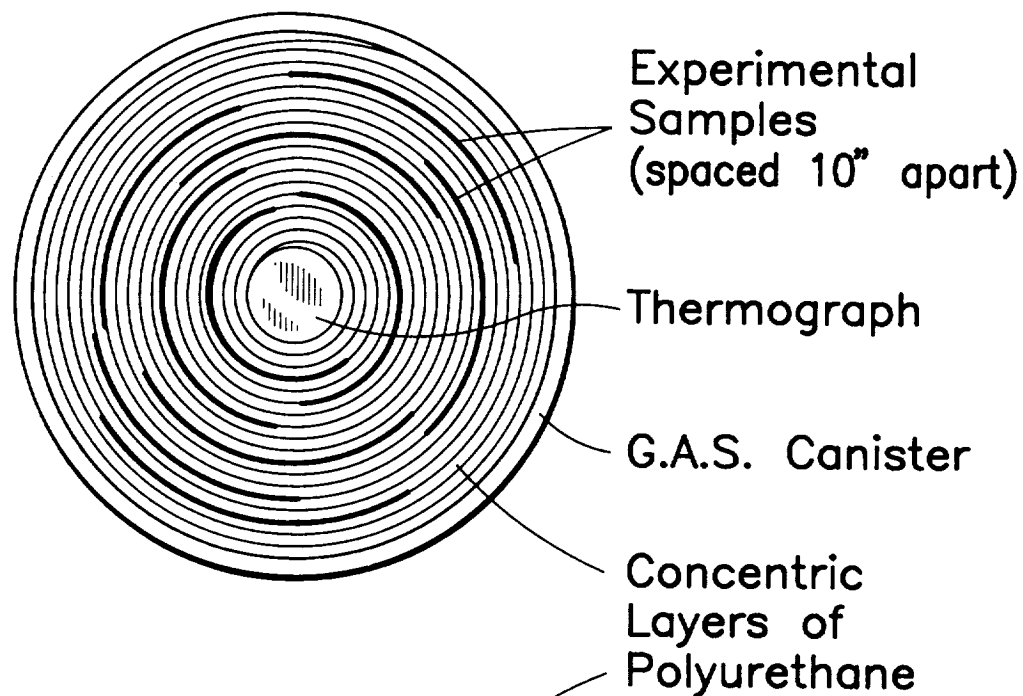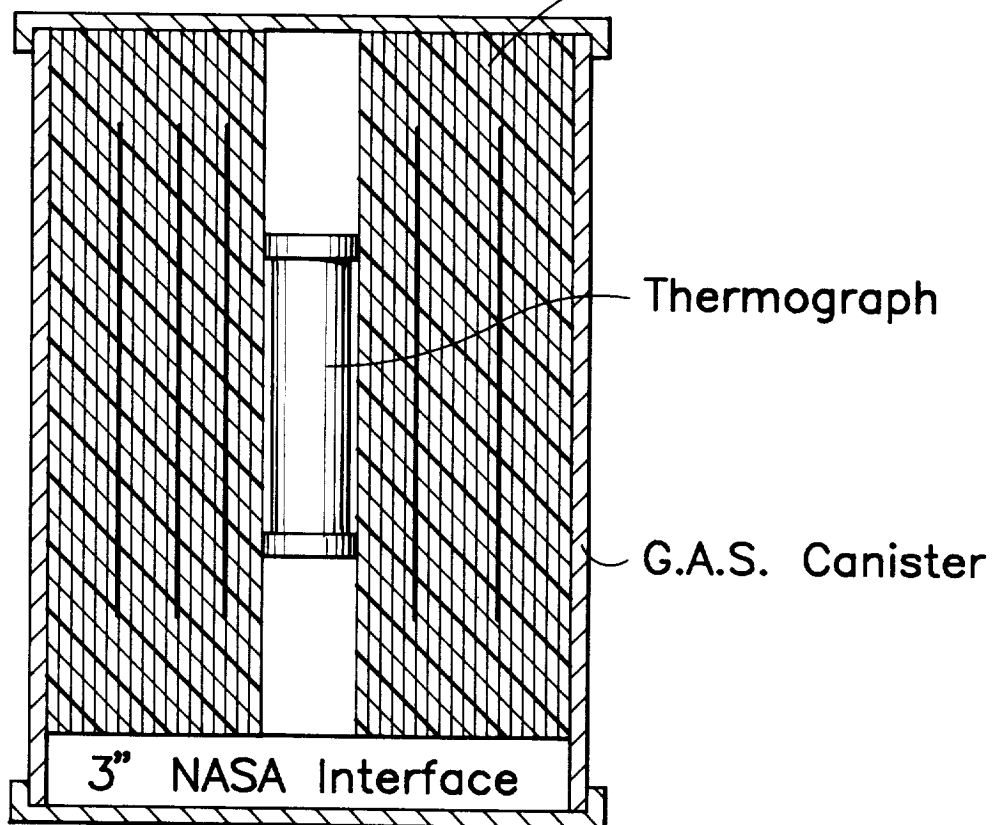
G.A.S. Payload #481
Vertical Horizons

E. Three 19 x 15 inch samples of double-primed Belgian linen painted
    with oil colors (DPP1)
F. Tattletale™ Thermograph: 2 inch diameter x 9 inch length, powered
    by 4 AA alkaline cells
G. One roll of polyurethene packing foam

Prior to containment in the G.A.S. canister, oil colors were applied with
traditional artist methods to the 19 x 15 inch samples of single-primed and double-
primed canvases. These samples were examined by the conservation department of
the Julius Lowy Frame and Restoring Company, Inc. in New York City. The following
examinations were performed:

A. Visual
B. X-ray
C. Ultraviolet
D. Solvent tests with acetone and toulene

Upon completion of the examinations, a random selection process was under-
taken to determine which samples would be placed into the G.A.S. canister and
which samples would remain on Earth as controls. The samples were marked and
recorded. The samples selected for placement aboard the Space Shuttle were con-
centrically rolled between layers of polyurethene foam. The materials were placed
in the G.A.S. canister for transportation to the Kennedy Space Center. Upon
arrival at K.S.C. the experimental samples were removed from the shipping canister
and placed into a 5 cubic foot G.A.S. flight canister. The thermograph was in-
serted into the center of the concentrically rolled polyurethene foam. The
canister was sealed and purged with dry air. The canister was placed onboard
the Space Shuttle Columbia for flight STS-61C. The mission lasted just over six
(6) days, at which time the canister was returned to K.S.C. from the Edwards Air
Force Base.

Upon recovery of the G.A.S. canister from K.S.C., the experimental samples
were removed and subjected to re-examination using the previously noted methods.

RESULTS

Following examination and testing of the experimental and control samples
(see condition reports), a comparison of the test results demonstrated the
following:

A. The linen and painted surfaces showed no signs of oxidation.*
B. The surfaces showed no accumulation of foreign substances.
C. The surface layers were fully intact with no evidence of cracking,*
    or flaking* of the pigments.
D. There was no sign of cupping* or cleavage.*

Temperature changes within the G.A.S. canister were not recorded due to an
error in the programming of the thermograph.

CONCLUSIONS

When fine arts materials are transported in the method adhered to in this
experiment, no sign of degradation is apparent. We may therefore conclude that
materials of the fine arts can be transported for limited periods of time into
space and returned safely.

*refer to Glossary for definitions

FUTURE PLANNING

Mankind has migrated to and colonized most of the habitable land mass on Earth and wherever he has chosen to live, he has brought art with him or created it anew. Our research represents a first step in the safe transportation of art into man's newest frontier, Space.

Taking this into consideration, future experiments may focus their examinations on the following:

A. The effects of long duration flights.
B. Exposure of the materials directly to the space environment.
C. Transportation of other cultural items (i.e., sculpture and mixed media).
D. Development and transportation of materials to be used in creating new items of cultural value in space.

We fervently hope that projects such as ours will inspire a global consciousness and demonstrate that the peaceful use of space is essential if we are to make space exploration a productive venture for mankind.

ACKNOWLEDGEMENTS

GLOSSARY

1. Abrasion: "Pictures are subject to all kinds of abrasions... Scratches occur most frequently when the picture is being transported. A single scratch on a precisely gradated painting can be disastrous."

2. Cleavage: "A painting develops cleavage when the support contracts resulting in the loss of bond between the ground and support or laminated layers of the paint. Cleavage or buckling is not always visible in the early stages. The loss of adhesion may at first appear as a slightly inflated air pocket rising from the paint surface."

3. Cracking: "Some (paintings) develop cracks more quickly than others depending upon the soundness of construction and the judicious choice of material. Prolonged movement, instability of the support or inadvertant pressures cause disfiguration... Changes of temperature and environment can cause the support to expand and contract producing cracks that penetrate through the ground to the paint... Allowed to continue, the stress of movement produces a widening of the cracks and further splitting."

4. Cupping: "A curling or cupping of the paint may accompany the cleavage as a result of further stress in the support. Intersecting cracks form small islands in the paint film and the loss of adhesion causes the paint to curl upwards."

5. Flaking: "The movement and stresses of the support are instrumental in cracking and cleavage of the layers, causing the paint to lose bond and become detached. This condition is called flaking."

6. Oxidation: "Oxidative breakdown of the paint medium leads to weight loss and this has been used to measure the rate of oxidation which is normally associated with cracking due to the erosion of the (paint) film surface."

Reference: Kelly, Francis, Art Restoration: A Guide to the Care and Preservation of Works of Art, McGraw-Hill Book Company, New York (1972).

CONDITION REPORT #1   Sample #'s Control and Exp. Samples (UP1)
                                                             (SP1)
                                                             (DP1)

Date: 4/14/87

Artist: Size in inches: 16 x 12

Medium: Unpainted Canvas   Size in cm. : 40.6 x 30.5

Surface Coating: ___Varnished   X Unvarnished

Paint film: Medium is characteristic of <u>no paint film</u>

Conditions:

No Discoloration: fading, yellowing, blanching, grime, darkening, dirt
No Cleavage: flat cleavage, buckled or cupped
No Embrittlement: flaking, chipping, paint of ground loss
No Cracking: paint and/or ground cracking
No Damages: abrasions, punctures, tears, dents
___ Additional observations:

Yes Condition sound

Support:

Canvas: <u>Belgian linen in various states of preparation</u>

_X_ Observations of condition: <u>Excellent</u>

Examinations performed:

_X_ Visual
_X_ Ultra-violet light
_X_ X-rays
___ Solvent tests: _____

|

CONDITION REPORT #4   Sample #'s Control and Exp. Samples (SPP1)
                                                        (DPP1)

Date: 4/24/87

Artist: Ellery Kurtz   Size in inches: 19 x 15

Medium: Oil on linen canvas   Size in cm.   : 48.3 x 38.1

Surface Coating: ___Varnished   _X_Unvarnished

Paint film: Medium is characteristic of oil paints

Conditions:

No Discoloration: fading, yellowing, blanching, grime, darkening, dirt
No Cleavage: flat cleavage, buckled or cupped
No Embrittlement: flaking, chipping, paint of ground loss
No Cracking: paint and/or ground cracking
No Damages: abrasions, punctures, tears, dents
___ Additional observations: No sign of oxidation

Yes Condition sound

Support:

Canvas: Belgian linen with single and double coat of alkyd priming

___ Observations of condition: Excellent

Examinations performed:

 X Visual
 X Ultra-violet light
 X X-rays
 X Solvent tests: Toulene and acetone _____

119

INORGANIC CHEMICAL PRECIPITATE FORMATION PAYLOAD DESIGN

by Craig Friedrich, Ph.D.

Department of Mechanical Engineering

Louisiana Tech University

ABSTRACT

The ever increasing use of the microgravity environment in materials research prompted the investigation of the formation of inorganic precipitates. Sponsored by the Frontiers of Science Foundation of Oklahoma and built at Oklahoma State University, G-405 utilizes six transparent chemical reaction chambers to actively mix a dry powder with a liquid solution. At predetermined intervals the progress of the precipitate formation is photographed and stored as data. The precipitate particles will also be subject to post-flight analysis. The various tasks performed during the 14 hour duration of the experiment are initiated and monitored by a custom-built digital controller. The payload, originally scheduled and shipped for flight in 1986, is currently scheduled as the backup payload for STS-29 with a possible launch date of January, 1989.

BACKGROUND

The Frontiers of Science Foundation of Oklahoma sponsored a competition among local high school students to conceptualize a payload for space research. Mark Rubowitz and Clay Collins, two juniors at Casady School in Oklahoma City, proposed the investigation of inorganic chemical precipitate formation in the microgravity environment. Their interest in this research area was cultivated by several years of laboratory investigations and encouragement by science fair participation. The Foundation then funded the payload development at Oklahoma State University and, after a two year developmental period, the payload was ready for flight STS-61C.

CHEMICAL EXPERIMENTATION

The precipitate reactions which will be carried out by the payload are shown below. The first compound is the dry powder for that chamber, the second compound is the liquid for that chamber, and the fourth compound is the precipitate for that chamber.

1) $MnSO_4 + 2KOH \quad K_2SO_4 + Mn(OH)_2$ a yellow gel precipitate

2) $NiCl_2 + 2NaOH \quad 2NaCl + Ni(OH)_2$ a green gel precipitate

3) $MnSO_4 + Ba(OH)_2 \quad MnO_4 + BaSO_4$ a white crystal precipitate

4) $K_2Cr_2O_7 + 2AgNO_3 \quad 2KNO_3 + Ag_2Cr_2O_7$ a brown crystal precipitate

5) $Hg(NO_3)_2 + 2NaCl \quad 2NaNO_3 + HgCl_2$ a white curdy precipitate

6) $NaCl + AgNO_3 \quad NaNO_3 + AgCl$ a white curdy precipitate

Precipitate formation first depends on the presence of a solution which is saturated with a relatively insoluble salt. If the solution is supersaturated, the salt will leave the solution as a precipitate until the solution is once again saturated. In the gravity environment this process is very dependent upon localized concentrations within the supersaturated solution. With the heavier precipitate particle settling out, the solution may be physically mixed which will aid in precipitate formation or the solution may become stratified which will create zones of precipitation similar to the nucleation sites within a solidifying metal alloy. In the microgravity environment though, the precipitate formation will be dependent only upon the localized solution concentration. This of course assumes a constant temperature throughout the solution. The data from the precipitate formation will be taken by means of photographs of the formation as well as post-flight analysis of the precipitate particles.

THE MIXING CHAMBERS

The purpose of the six mixing chambers is to allow photographic data of the particle's formation, to contain the chemical reactants, and to provide a forced mixing of the two reactants in each chemical chamber. The first two purposes are easy to accomplish through the use of relatively thick-walled plexiglas tubing and rubber O-rings. The task of force mixing the reactants became the challenge. Several active mixing schemes were addressed but all of these ideas were too complex and space consuming. Having worked as a hydraulic system designer in industry, the problem of differential volumes within an enclosed cylinder finally had a good use. In a conventional hydraulic cylinder, one side of the piston is connected to a rod which exits the cylinder body. The other side of the piston does not typically have a rod attached to it. When the cylinder

piston is moving, more fluid is being displaced on the non-rod side of the piston than on the side of the piston which contains the rod.

In the reactant chamber used for this payload it is necessary to use an arrangement which has a rod running the entire length of the cylinder. It is impractical to use a rod of varying diameter to establish the differential volume relationship, therefore this is accomplished by using two sizes of plexiglas tubing. The mixing chamber design is shown in Figure 1. The cylinder piston is shown in its preactivation configuration. Upon activation, the cylinder spring will force the piston to move and the O-ring seal between the chemical reactants will be broken. In addition the downstream chamber half has a slightly larger inside diameter than the upstream chamber half. This open annulus around the piston will allow fluid to be forced to the back side of the piston which will create the forced mixing. In tests this concept has worked with great success. An additional plus for this design is that there is only one moving part and the driving force is a spring which is compressed prior to flight, adding to the system reliability. The cylinder piston contains one O-ring seal to keep the reactants apart prior to activation. The cylinder body also has O-rings in each end to help eliminate reactant leakage into the canister interior. The cylinder body also contains absorbant material just outside of the cylinder O-rings to add an additional level of protection against reactant leakage.

To better maintain a consistent temperature within the six reaction chambers, each chamber is wrapped with two flexible resistance heaters. The heaters are each about two feet long, covered with woven fiberglas, and composed of teflon coated wires. Originally designed for use at 120VAC and 100 watts, the heaters are operated at 12VDC and put out one watt each. The heaters operate at about 90 degrees F and offer 12 watts of heat capacity at a relatively low temperature. The heaters are thermostatically controlled to become active below 60 degrees F.

SPECIAL DESIGN CONSIDERATIONS

It was necessary to design for a catastrophic failure of all six reactant mixing chambers. Several of the liquid reactants are caustics which readily dissolve aluminum. Because the entire structure is nade of 6061-T6 aluminum, it was necessary to coat the structure with an inert resin. Because of the flight acceptance, PT-201 from Products Techniques, Inc. was chosen. This resin was brushed on and then baked at 360 degrees F to expedite outgassing. The coating provides a hard surface which is resistant to caustics and also provides electrical isolation of the structure. Because the flight container is also made of aluminum, it was necessary to limit the caustic concentration so that there is no possibility of the caustics penetrating the canister thickness. If all of the caustics are allowed to attack the canister interior, the wall thickness of the canister would decrease by one-thousandth of an

123

inch. An additional consideration in the use of the caustics is the release of hydrogen gas upon reacting with aluminum. This consideration was the overriding factor for the maximum concentration of the caustic solutions. The caustic concentration is such that if all of the caustics react with the unprotected aluminum, the maximum buildup of hydrogen gas will be less than 3% by volume.

CONTROL CIRCUITRY

The control circuitry for the operational scenario of the payload is relatively simple. Upon astronaut activation, the circuitry maintains the reactant chambers in a dormant state for one hour. During this time, the thermal environment of the chambers is stabilized by way of thermostatically controlled chamber heaters. After one hour has passed, the reactant chambers are solenoid activated and the precipitation process begins. After several ground tests, it was learned that it is necessary to record the precipitate formation early in the experiment duration. A photograph of the formation will be taken once every minute during the first 12 minutes, then once every 10 minutes for the next two hours, then once every 50 minutes for a total of 36 exposures over a 14 hour period. The control circuitry uses a simple digital clock, counters and EPROM memories to control the duration between photographs.

In conversations with Goddard Space Flight Center personnel in totally unrelated matters, it was learned that some EPROM's are so susceptible to memory damage from radiation that they have actually been used as radiation detectors. This fact led to the use of three EPROM's to provide a "majority vote" logic scheme. The 2716 EPROM was selected because of its widespread availability and its ease of programming. This 16K memory chip was programmed with a 40 byte program. Though severely under-utilized, the chip was used because of the availability of the programming hardware. The output of the EPROM's are used as the input to the voting logic. The voting logic is used to address multiplexers so that the appropriate clock pulses activate the camera shutter. This arrangement is shown in Figure 2 and the arrangement for the majority voting logic circuitry is shown in Figure 3.

PREVIOUS FLIGHT SCHEDULING

G-405 was originally scheduled as first backup payload for STS-61C for a March 1986 flight. To meet this schedule, it was necessary to ship the completed payload to KSC in November of 1985. The payload has been held in storage at KSC until early May of 1988 when it was returned to Louisiana Tech University. This provided an excellent opportunity to examine any long-term storage effects on the payload systems. All aspects of the payload withstood the 2-1/2 year dormancy very well. The payload was originally shipped void of the chemicals so the chambers and seals were still in new condition. The battery pack was the only component which showed any

signs of age. The cells used were the Gates "X" cells, each with two volts and five amp-hours capacity. The cells were combined to provide a nominal 12 volts and 20 amp-hours capacity. When shipped the batteries were charged to approximately 13 volts. After 2-1/2 years in storage, the batteries had discharged to about 11 volts but the current capacity was greatly diminished. The battery pack was capable of driving the camera autowinder only several times before being completely inadequate. After voltage tests were performed on individual cells, it was found that four of the cells were in deep discharge (less than one volt output) and were incapable of being recharged. These four cells have been replaced. All other lower voltage systems such as the flash and the digital controller were still very functional. This clearly exhibits the excellent shelf-life of the lead-acid battery.

RECOMMENDATIONS

    As part of The National Space Transportation Systems's return to flight status all previously approved payloads are required to have conducted on them a Delta Phase III Review. This review requires further documentation as to tests performed on various payload systems and components. It is recommended that any tests performed as part of a hazard report verification be documented with the date and a report number. This additional work at the time of the test will save additional time and paperwork when the payload is going through the safety review process.
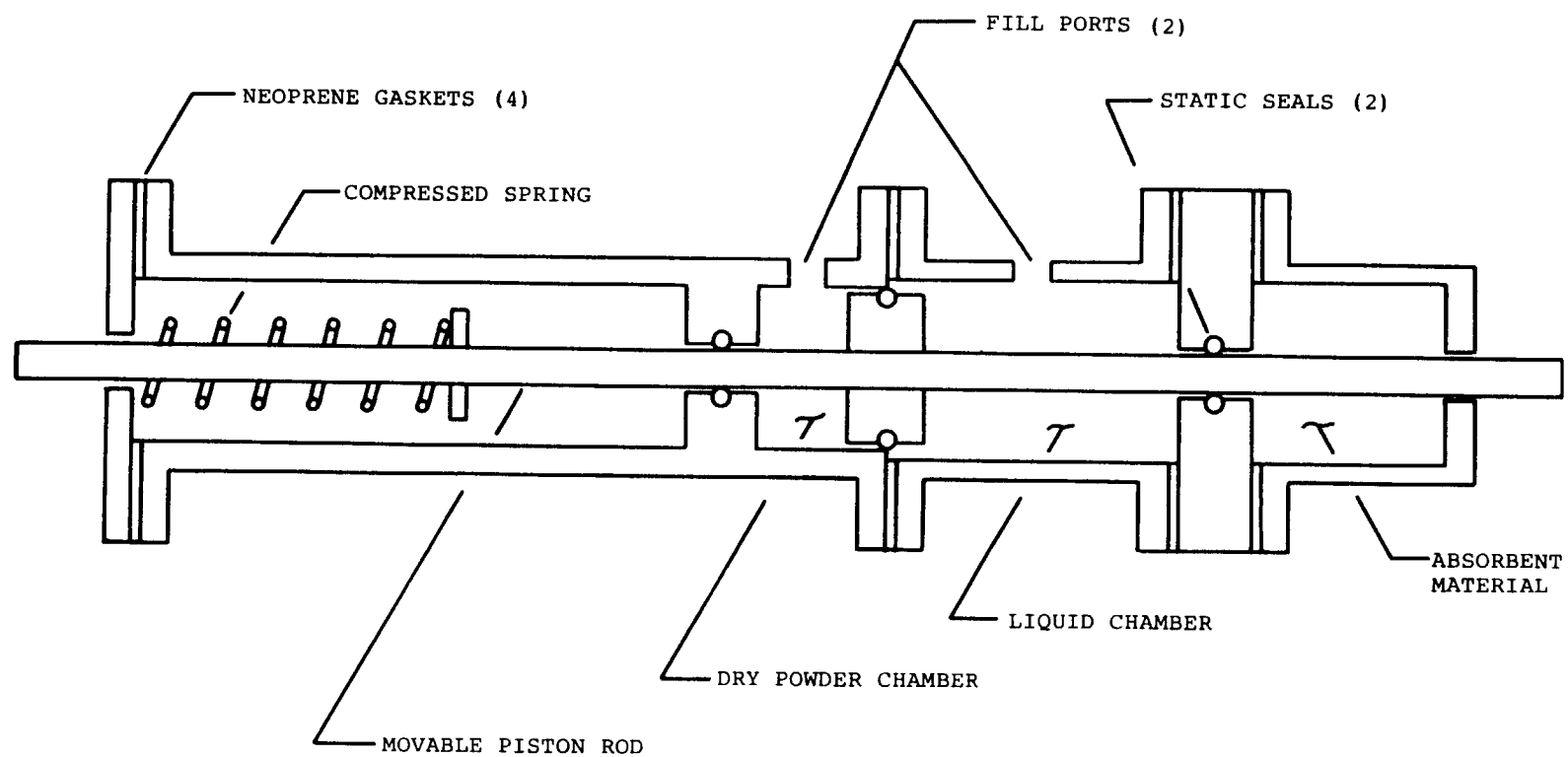
FILL PORTS (2)

NEOPRENE GASKETS (4)

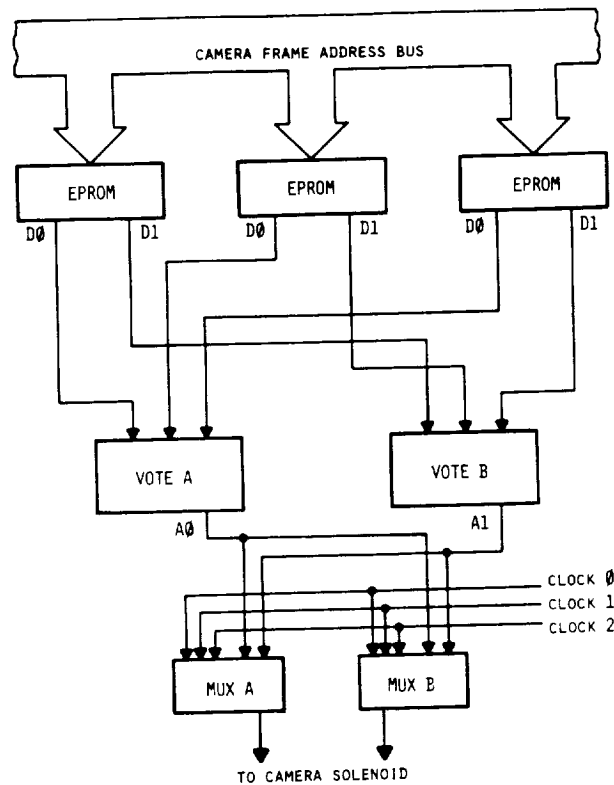STATIC SEALS (2)

COMPRESSED SPRING

ABSORBENT MATERIAL

LIQUID CHAMBER

DRY POWDER CHAMBER

MOVABLE PISTON ROD

Figure 1.   Precipitate Reaction Chamber

Figure 2.   Camera Shutter Activation Circuitry
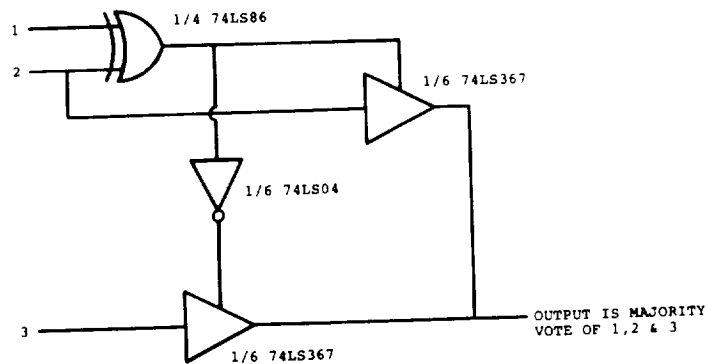
Figure 3.   Majority Voting Logic Circuitry

NASA

National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CP- 3008		

4. Title and Subtitle	5. Report Date
1988 Get Away Special Experimenter's Symposium	September 1988
	6. Performing Organization Code
	740

7. Author(s)	8. Performing Organization Report No.
Lawrence R. Thomas and Frances L. Mosier, Editors	88-158
	10. Work Unit No.

9. Performing Organization Name and Address	11. Contract or Grant No.
Goddard Space Flight Center Greenbelt, Maryland 20771	

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Aeronautics and Space Administration Washington, D.C. 20546-0001	Conference Publication
	14. Sponsoring Agency Code

15. Supplementary Notes

Frances L. Mosier is affiliated with RMS Technologies, Inc.; Landover, Maryland 20785.

16. Abstract

The 1988 Get Away Special (GAS) Experimenter's Symposium will provide a formal opportunity for GAS Experimenters to share the results of their projects. The focus of this symposium is on payloads that have been flown on Shuttle missions, and on GAS payloads that will be flown in the future.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Get Away Special - flown and future payloads	Unclassified - Unlimited Subject Category 12

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	136	A07

NASA FORM 1626 OCT 86